Recent Results from LHCf

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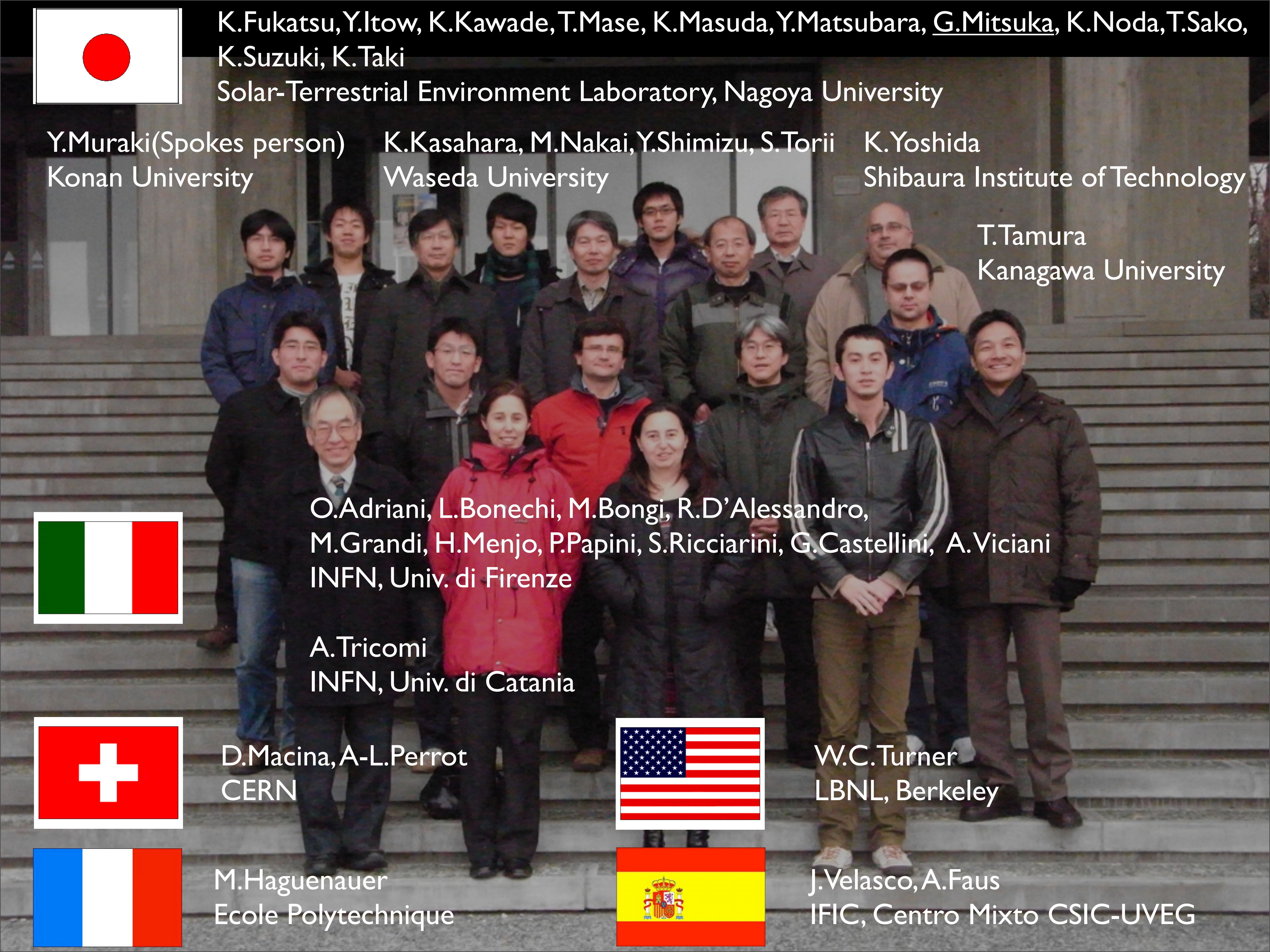
for the LHCf collaboration

22nd Rencontres de Blois
18 July 2010, Blois

Outline

- Introduction and Physics motivation
- The LHCf detectors
- Status of the LHCf experiment
- First results at $\sqrt{s}$=900GeV and 7TeV
  - All data at $\sqrt{s}$=900GeV
  - Focusing on March-May at $\sqrt{s}$=7TeV
- Conclusions and Future prospects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Totally ~40 collaborators

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Introduction

The LHCf experiment...

- aims to reduce the uncertainty of hadron interaction models around the TeV energy region using LHC, which are mainly used in cosmic ray experiments.
- observes neutral particles produced by the p-p collisions emitted in the very forward (including zero degree, η>8.4), equivalent to air-shower of cosmic ray.
- can discriminate the existing interaction models(e.g. DPMJET3, QGSJET, etc...) by comparison and provide crucial data for building future models.
- will contribute the ultra high-energy cosmic ray observations with high-precision.

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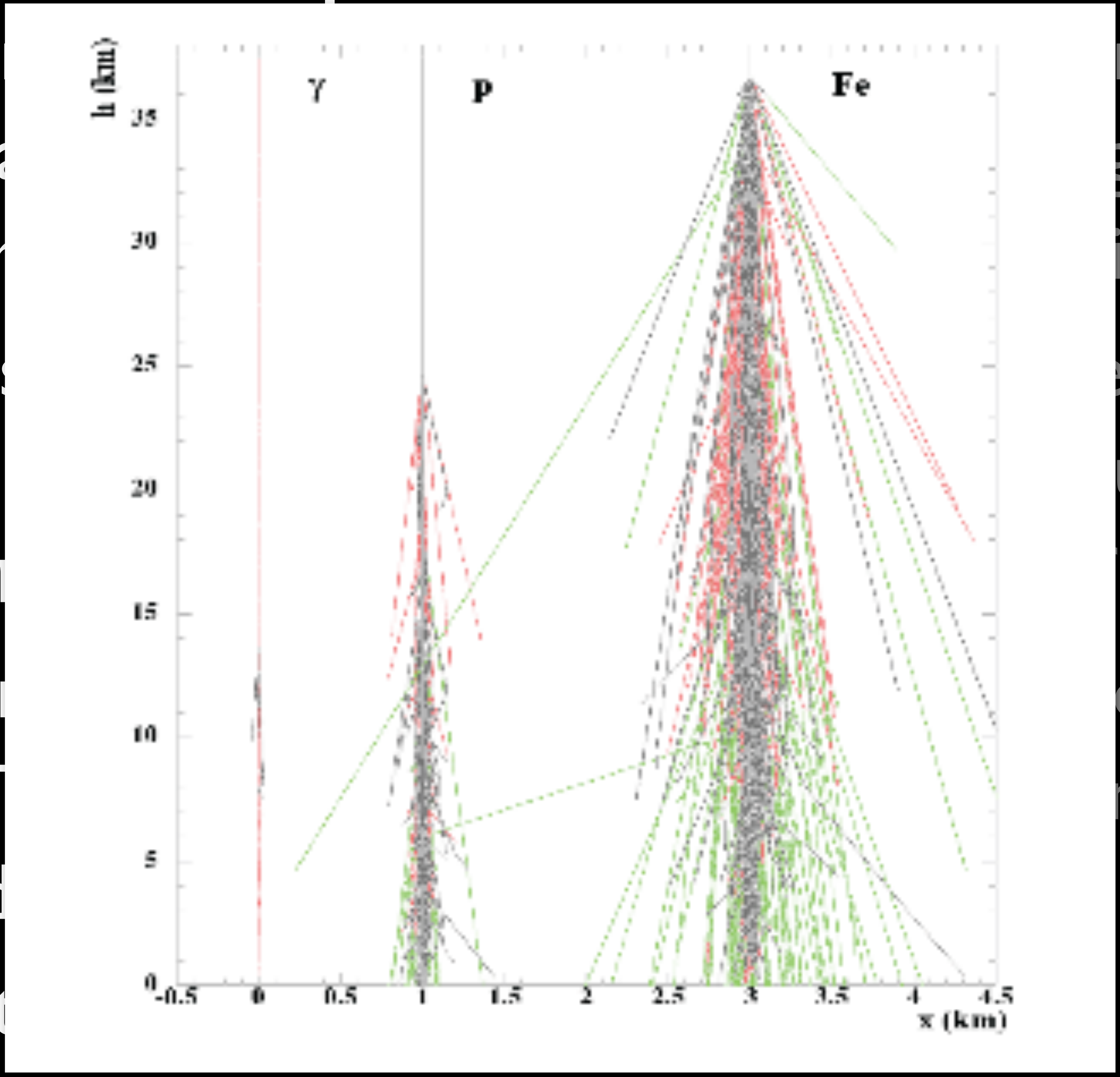

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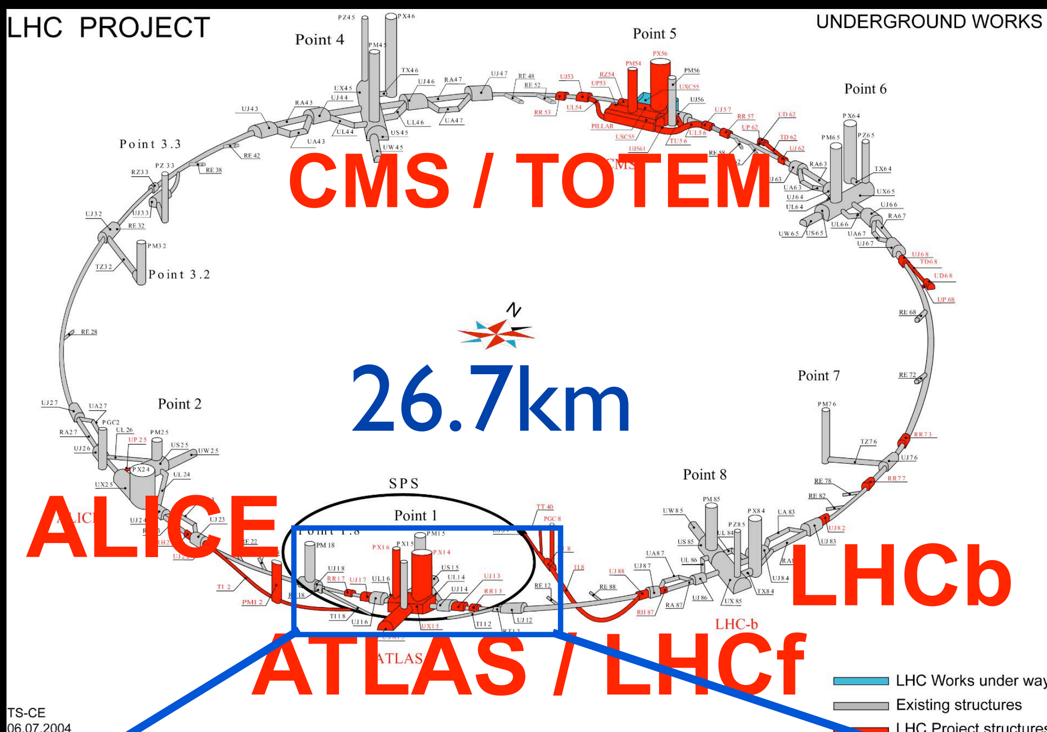
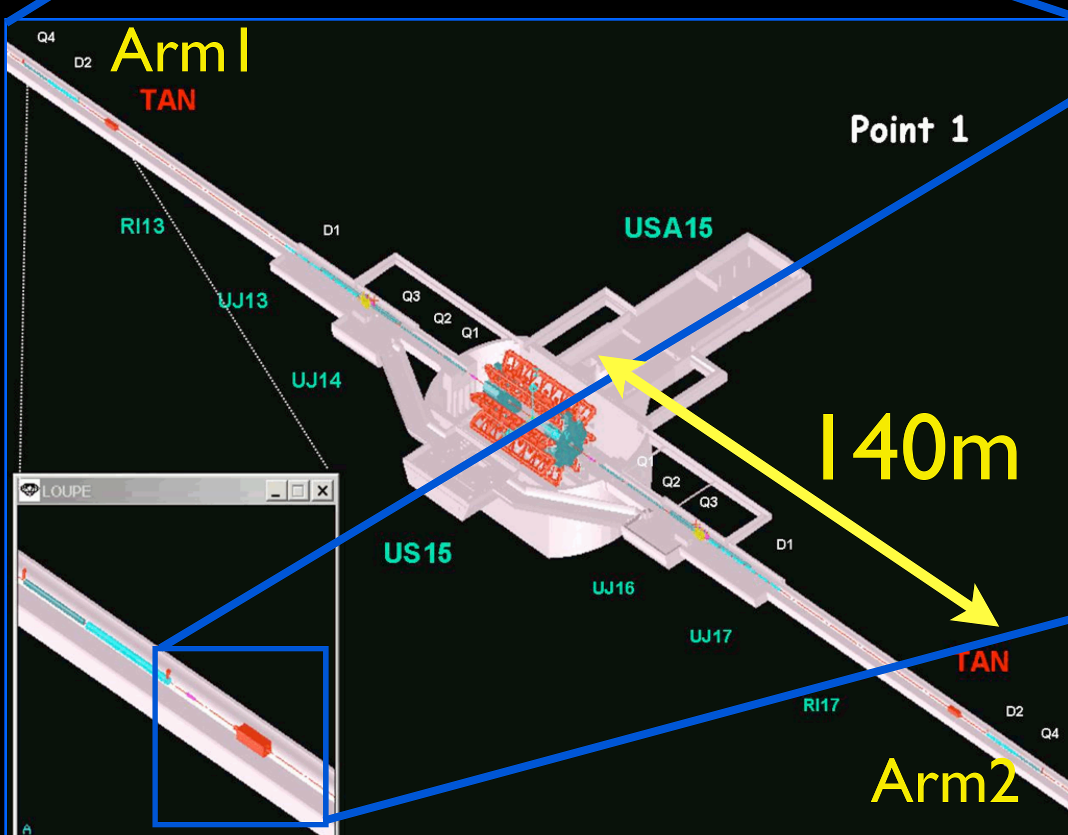
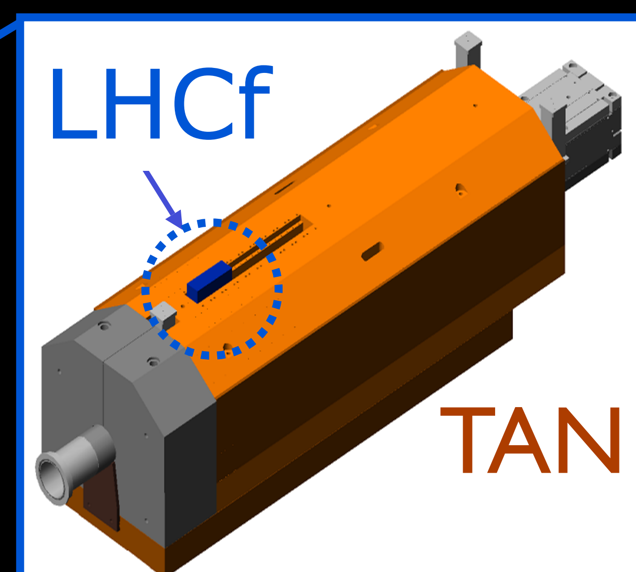
Forward measurements



- Zero degree instrumentation slot at 140m away from IP1(ATLAS).
- p-p collision at $\sqrt{s}$=14TeV corresponds to E_{lab}=10^{17}eV.





Forward measurements

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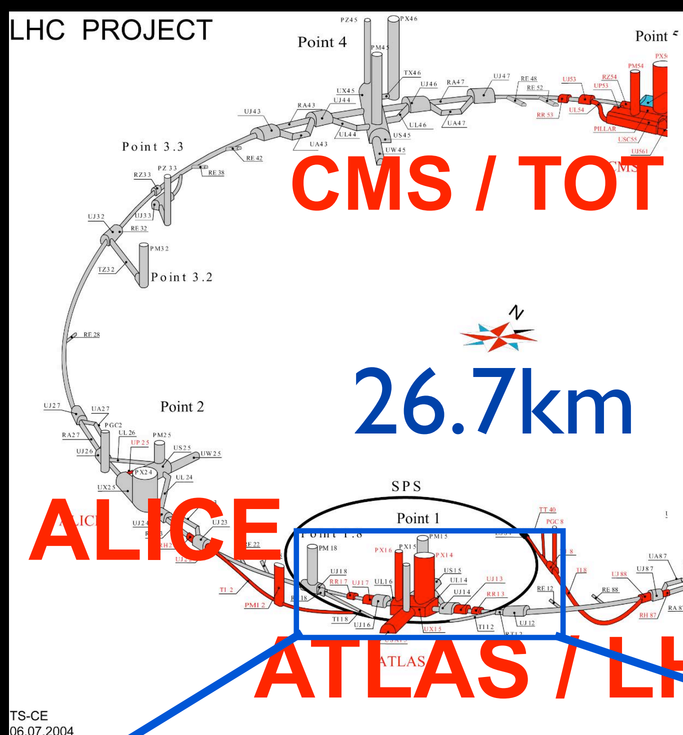
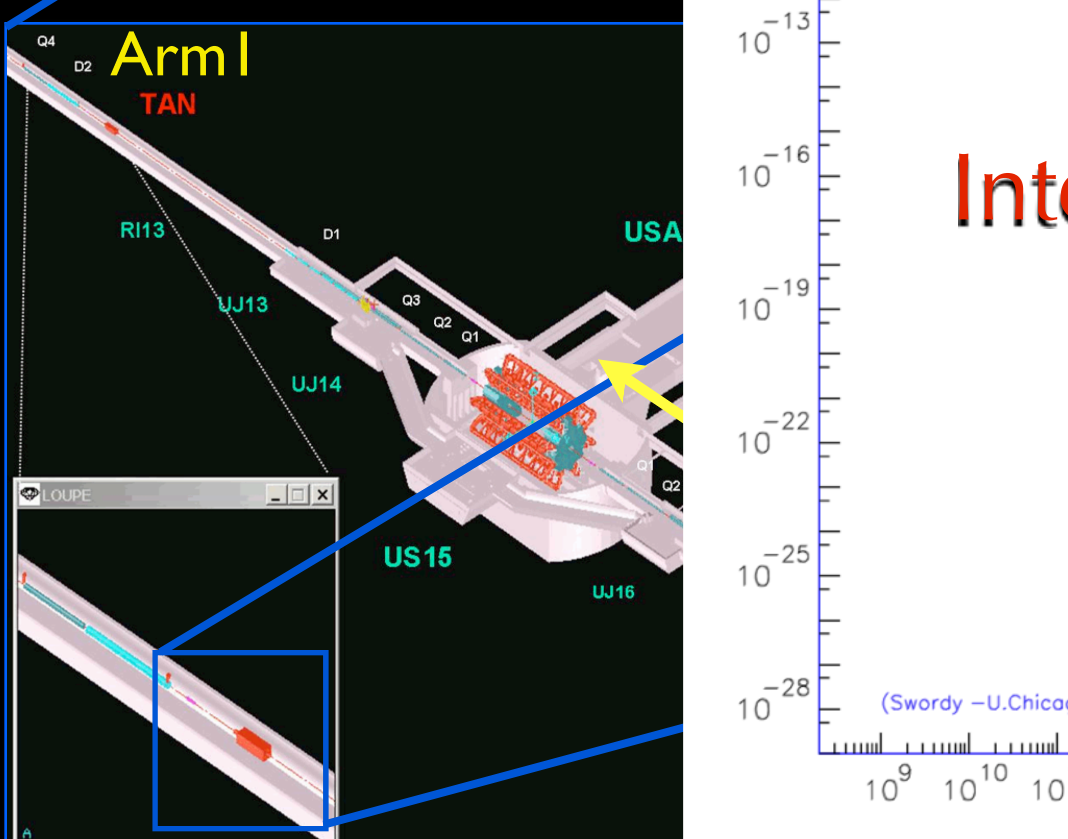
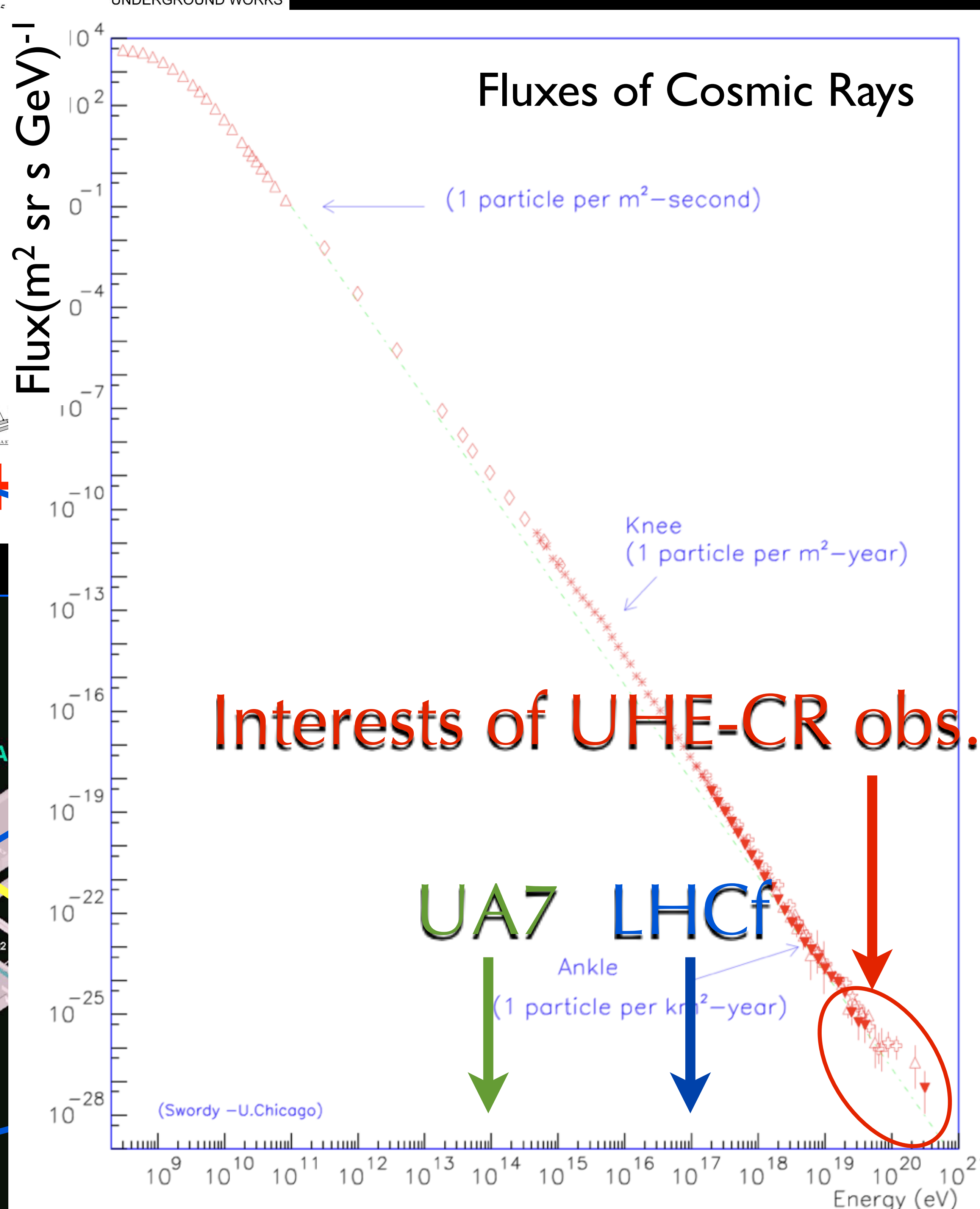
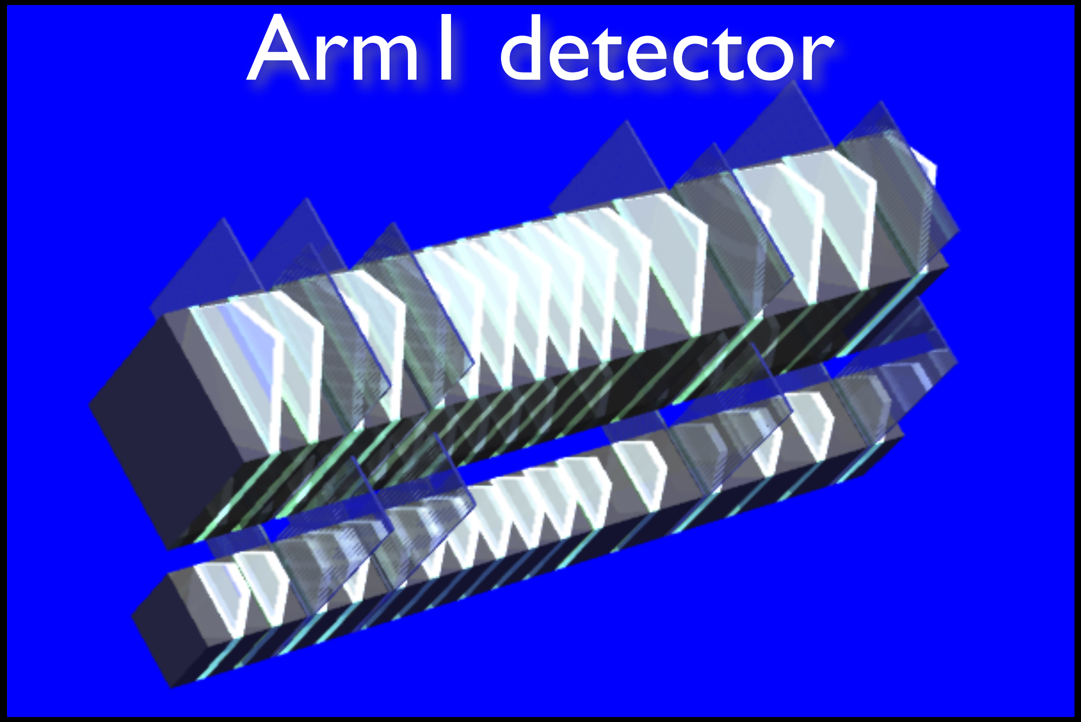




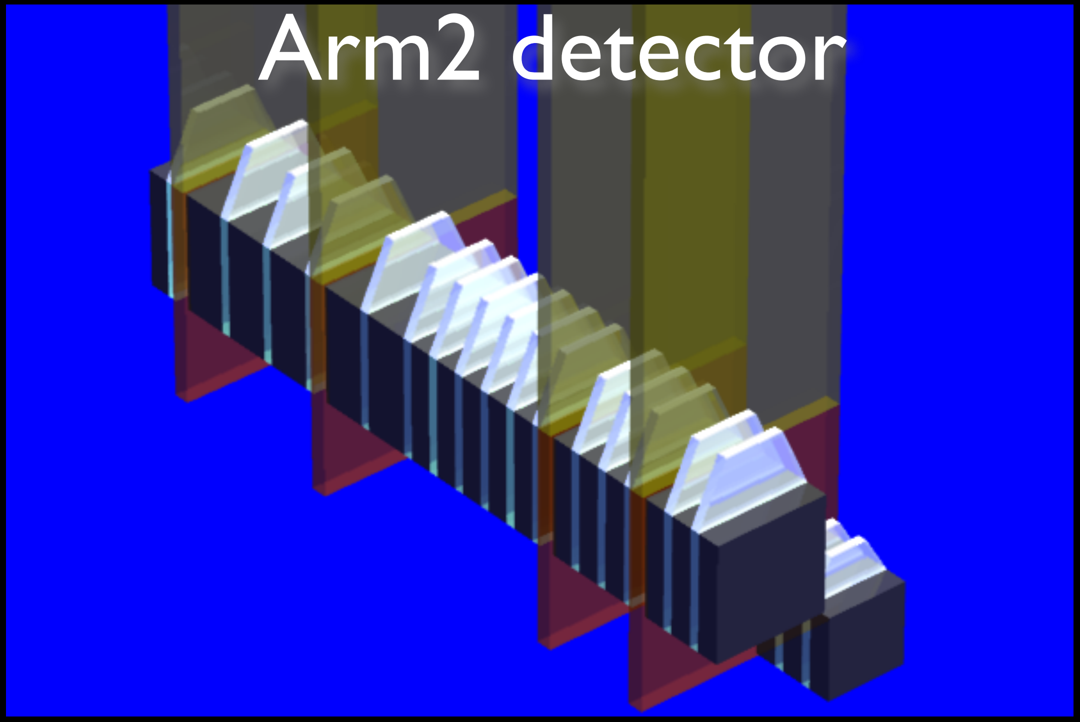


The LHCf detector

- Sampling & imaging calorimeters either side of IP1.
- Two compact towers in both detectors.
  - Tungsten absorbers: 44r.l., 1.7λ
  - 16 plastic scintillator sampling layers
  - 4 position sensitive layers

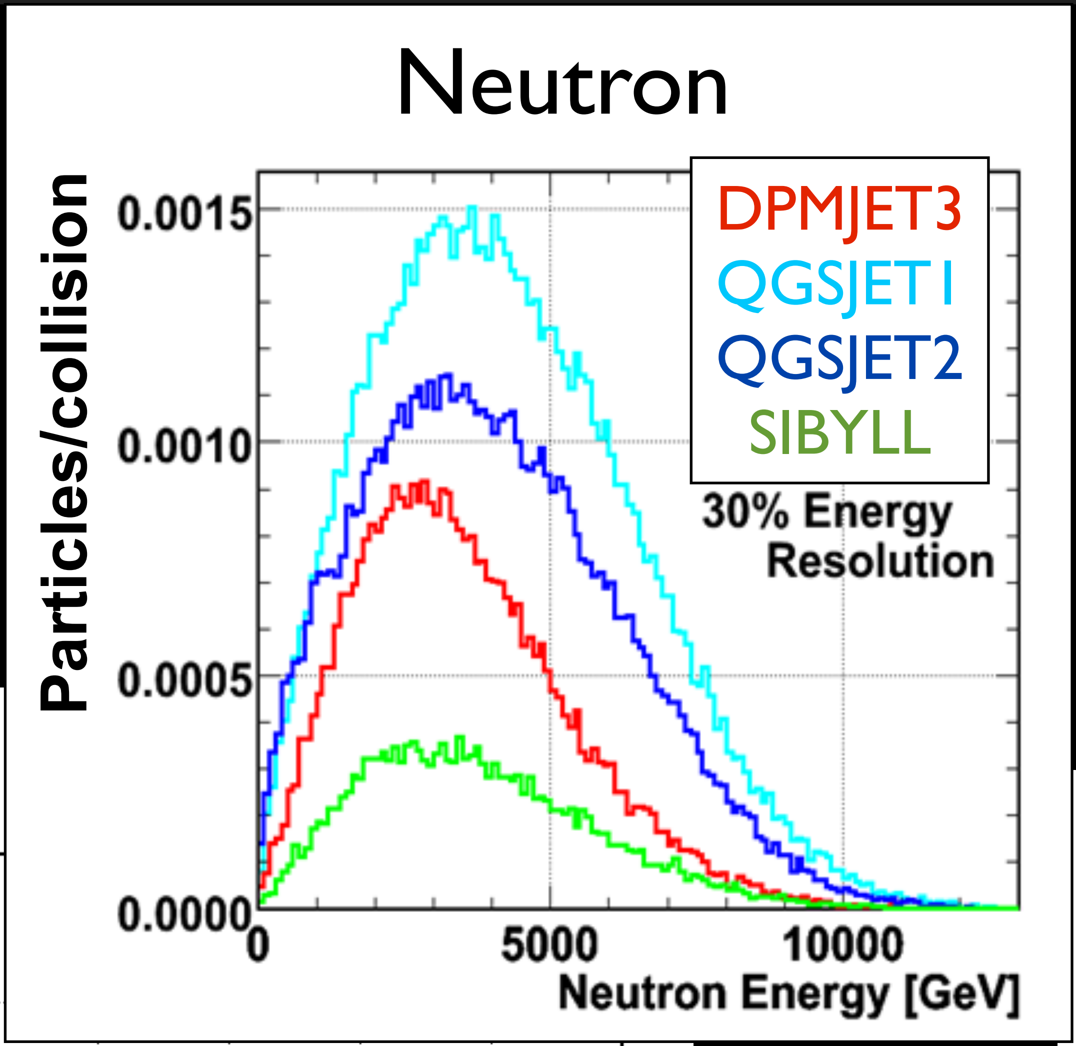


20mmx20mm + 40mmx40mm
Consists of scintillation fibers
Located at 6, 10, 30, 42 r.l.



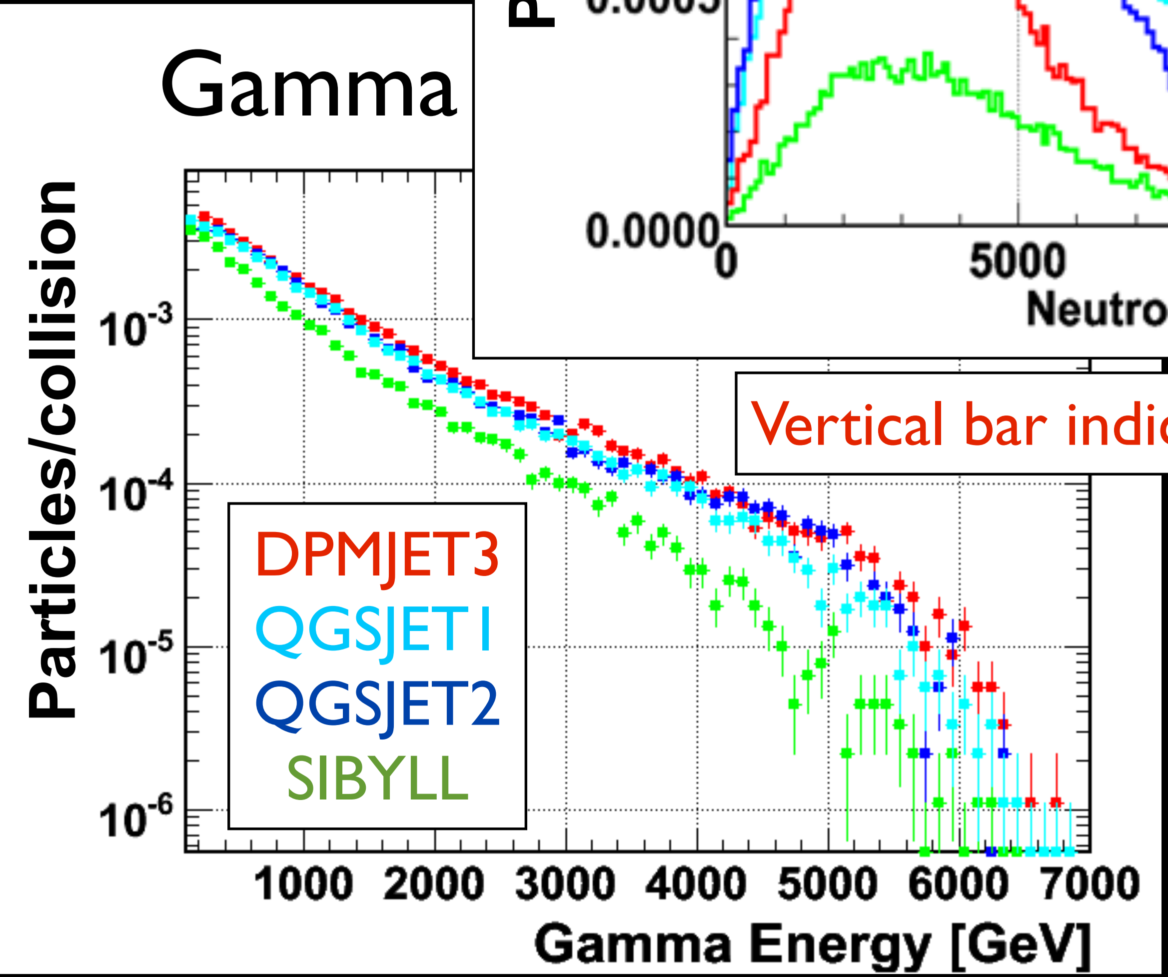
25mmx25mm + 32mmx32mm
Consists of silicon strip detector
Located at 6, 12, 30, 42 r.l.

Expected phenomena

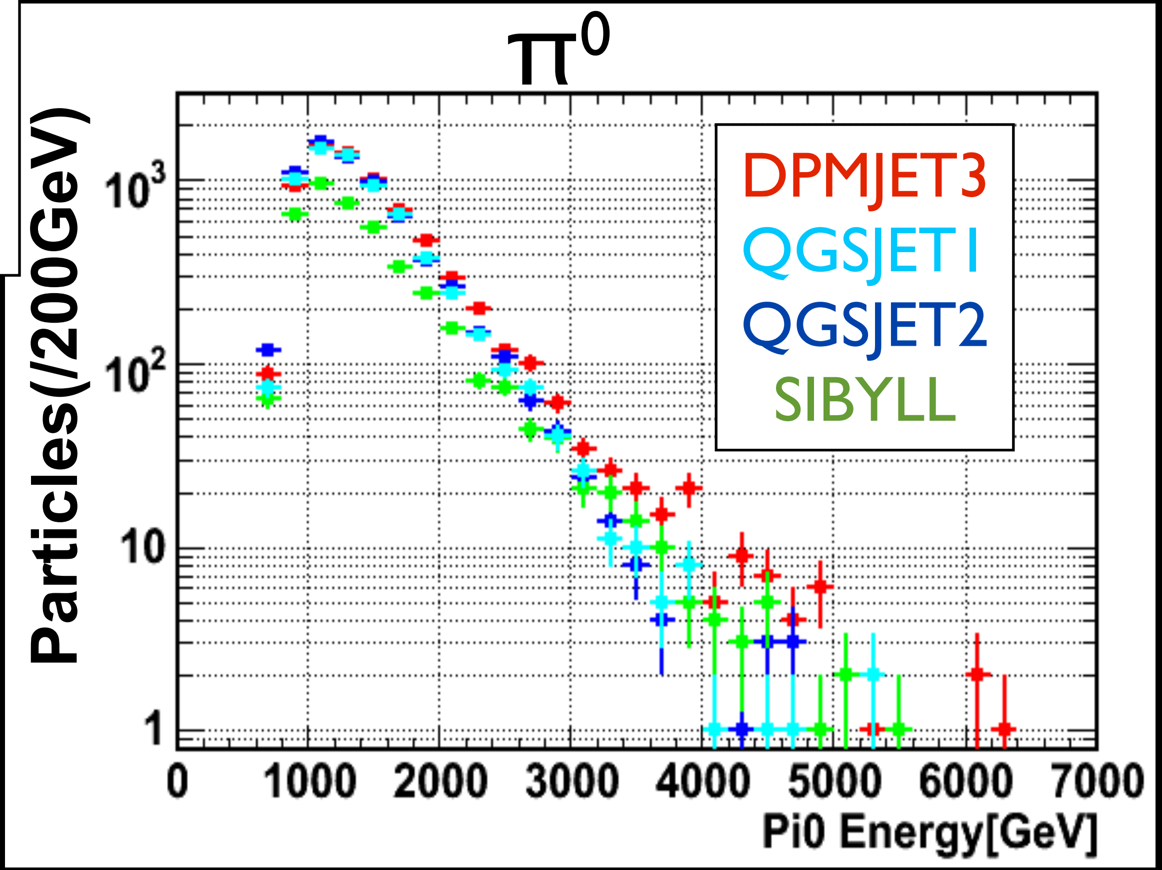


All figures assume 10^7 collisions@14TeV

- Spectrum in the forward region at 140m away from IP (=LHCf site).
- Energy resolution is taken into account by smearing the true energy instead of detector simulation.
- Neutron/Gamma ratio is also applicable to the discrimination.



Vertical bar indicates stat.err



Operation in 2009-10

Run in 2009

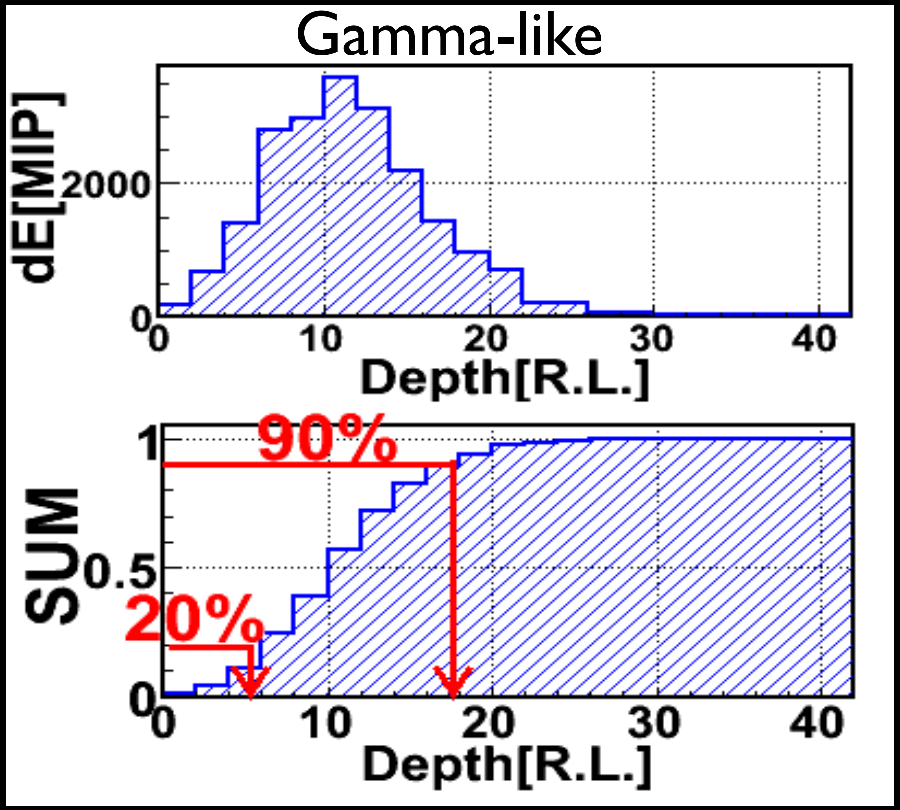
- From End of October 2009 LHC restarted operation
  - 450 GeV + 450 GeV → 1.2 TeV + 1.2 TeV
- Few weeks of 'smooth' running allowed LHCf to collect some statistics at 450+450 GeV in the stable beam conditions.
- Extremely useful period to debug all the system
  - No particular problem came out from the run
  - Detectors are working very well and in a stable way

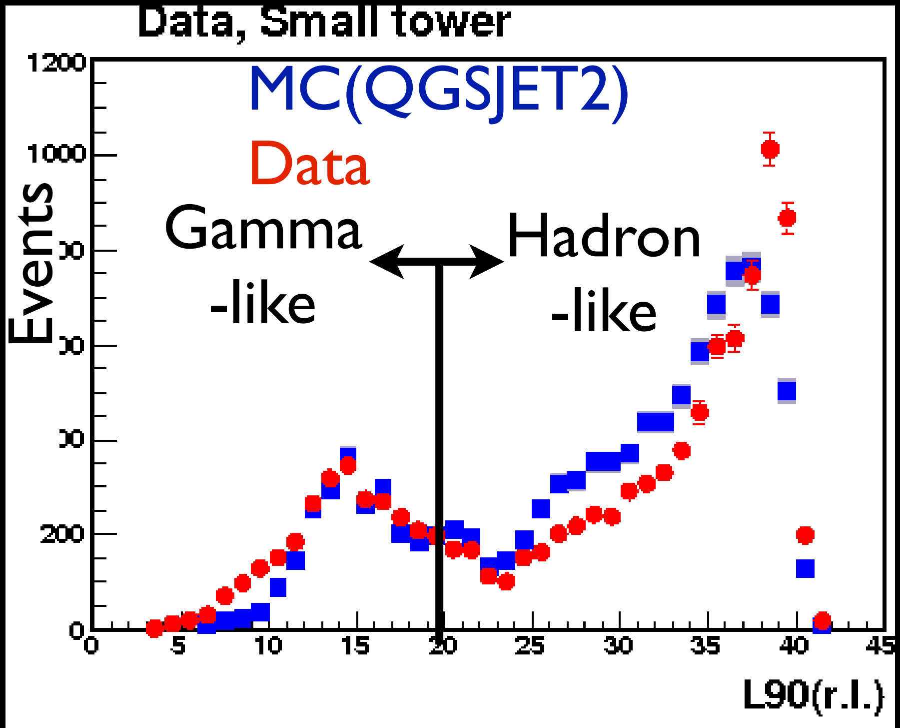
Run in 2010

- Successful data taking at 7TeV ongoing
  - Integrated luminosity ~ 14nb^{-1} until the technical stop on May.
  - 35M showers and 330K π^0s obtained (arm1+arm2).
  - Energy scale calibration with a π^0 peak.
- Statistics improved at 900 GeV >10times larger than 2009.
- Detector shows good performance with stable quality.
  - Good stability < ±2% level. No radiation problem until May.

Analysis@900GeV
(Run2009+2010)

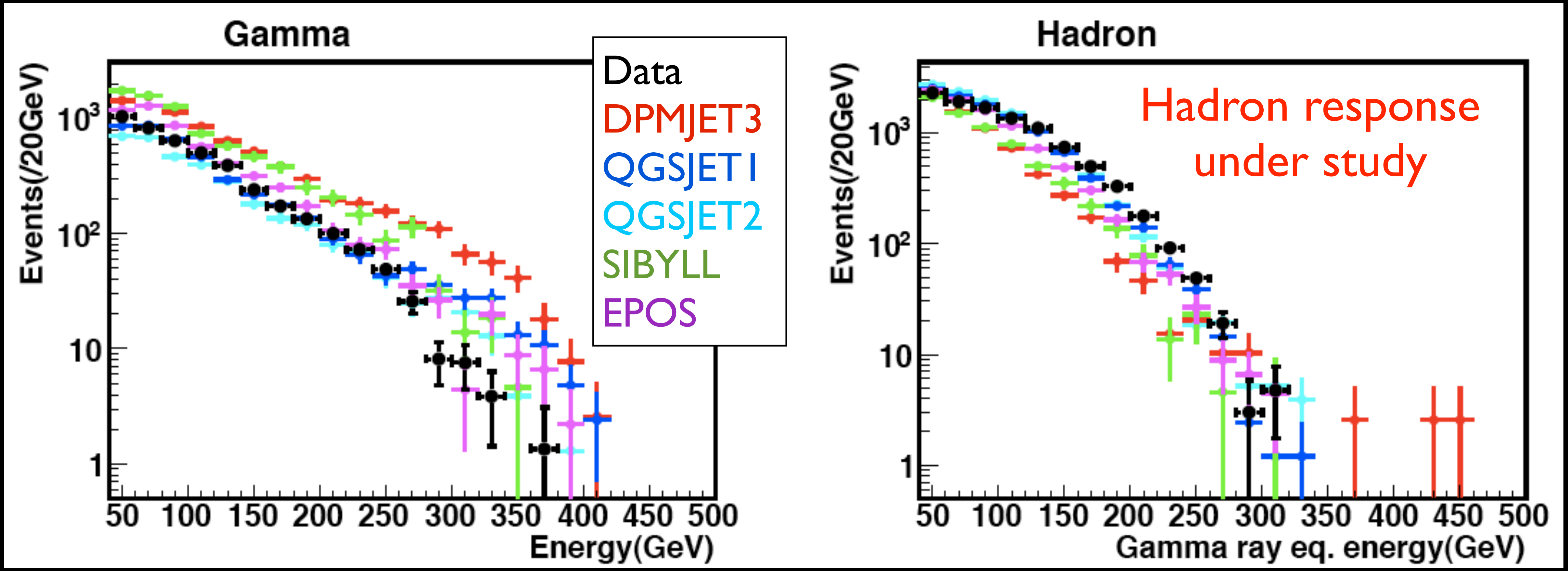
Particle Identification





- Gamma and hadron showers can be discriminated by the difference of the longitudinal shower development.
- Longitudinal development is parametrized with L20% and L90%.
- PID performance is checked with SPS calibration data taken in 2007.
  - 50-200GeV for electrons
  - 150, 350 GeV for protons
- ~90% purity both for gamma and hadron.
- PID study is still ongoing.

Spectra of 900GeV data

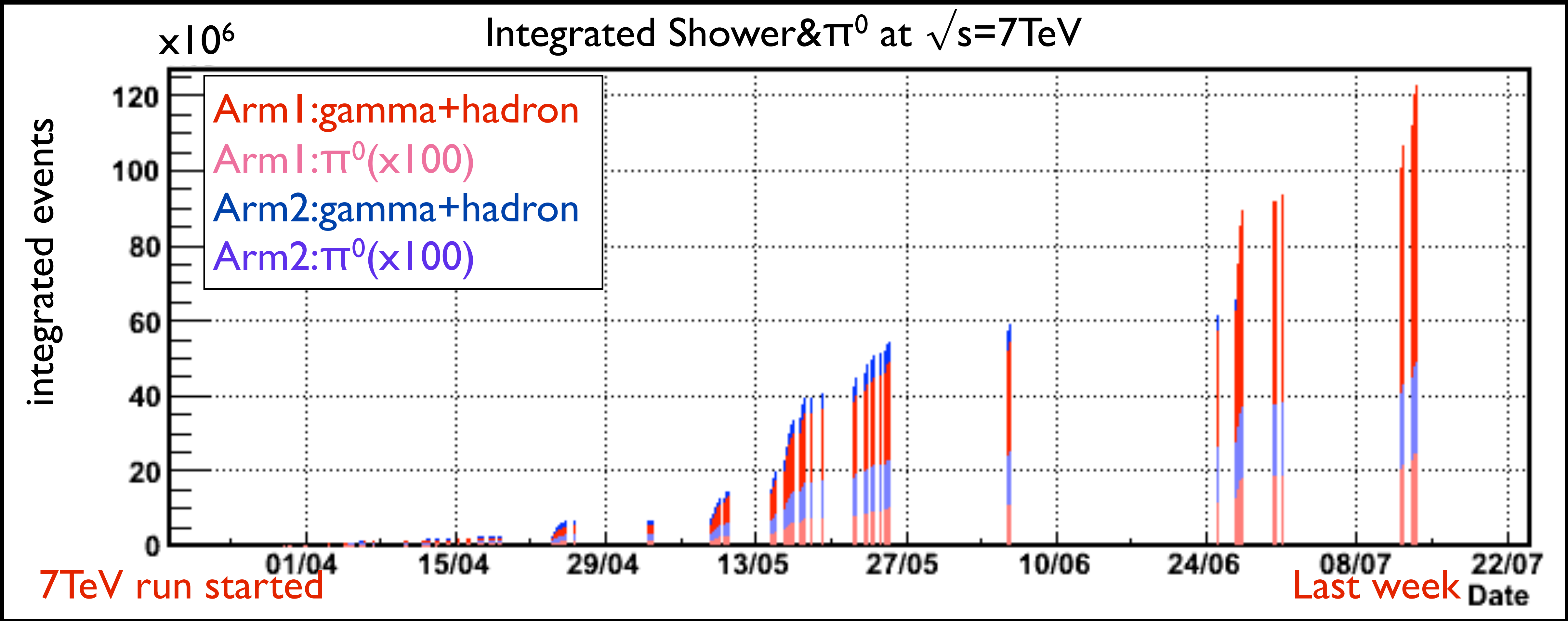


- QGSJET2 seems to agree with data, *but conclusion is too early*.
- Note that the detector response for hadron showers is under study with SPS 350,150GeV proton data and very conservative systematic error for energy scale +10%-4% must be taken into account.

More precise analysis is ongoing.

Analysis@7TeV

Statistics

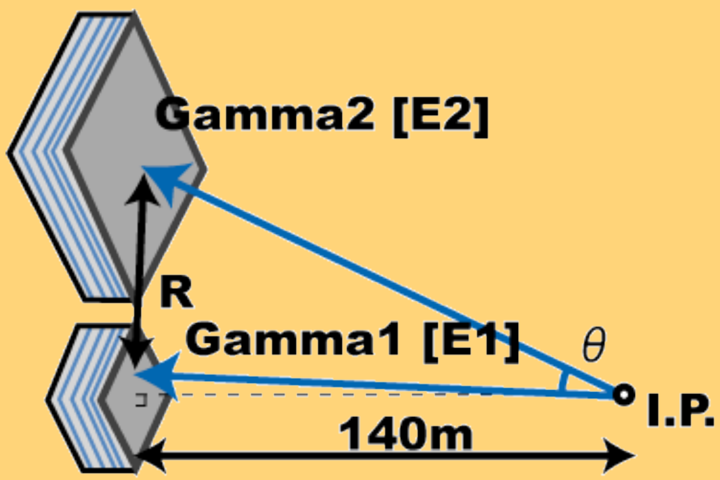


Total Statistics in March 30 - May 30

	Gamma-like	Hadron-like	π^0
Arm1	1.7E7	3.3E7	1.0E5
Arm2	1.8E7	3.5E7	2.3E5

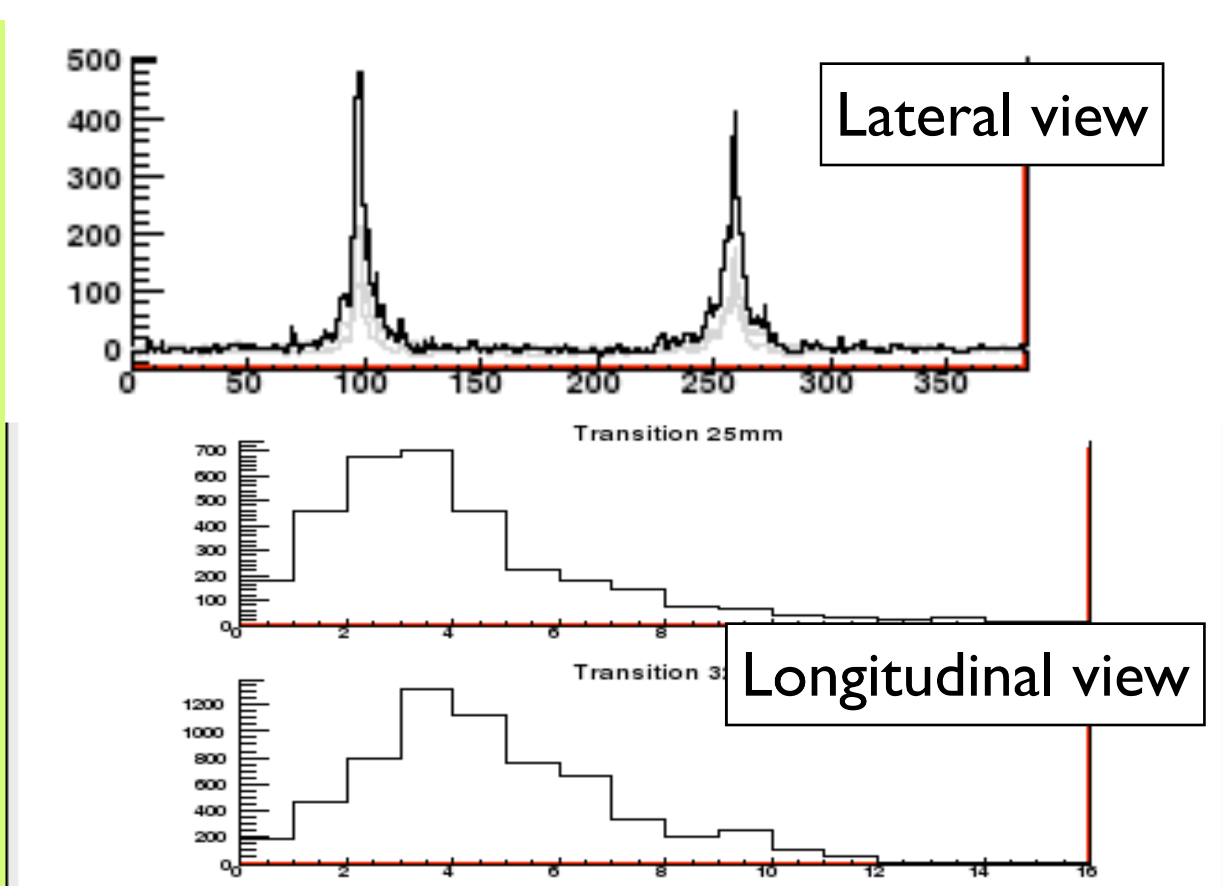
Data taking has been carried out quite stably.

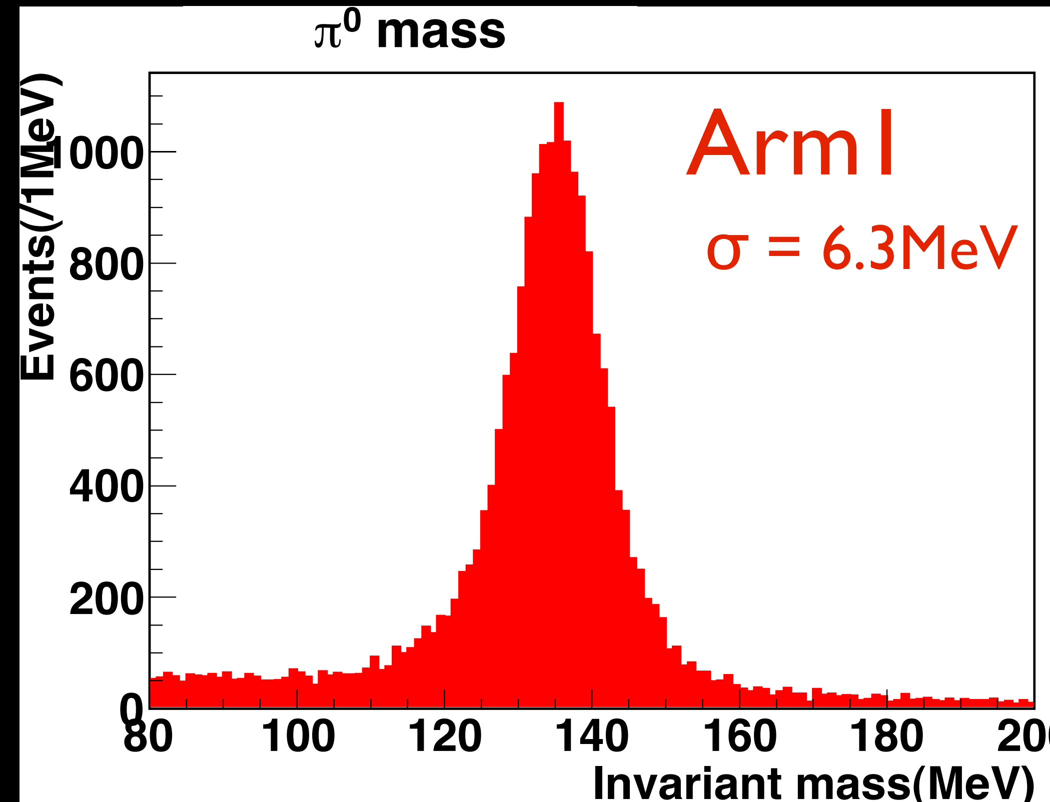
π^0 measurement

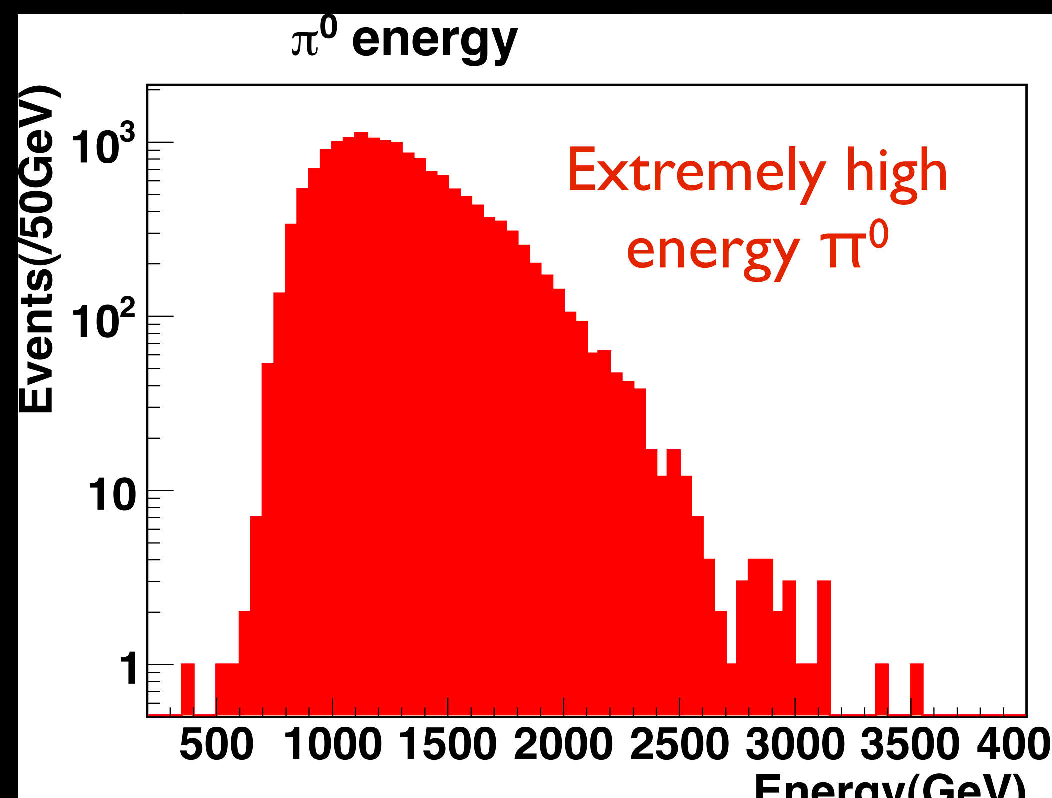


$$\theta = \frac{R}{140\mathrm{m}}$$

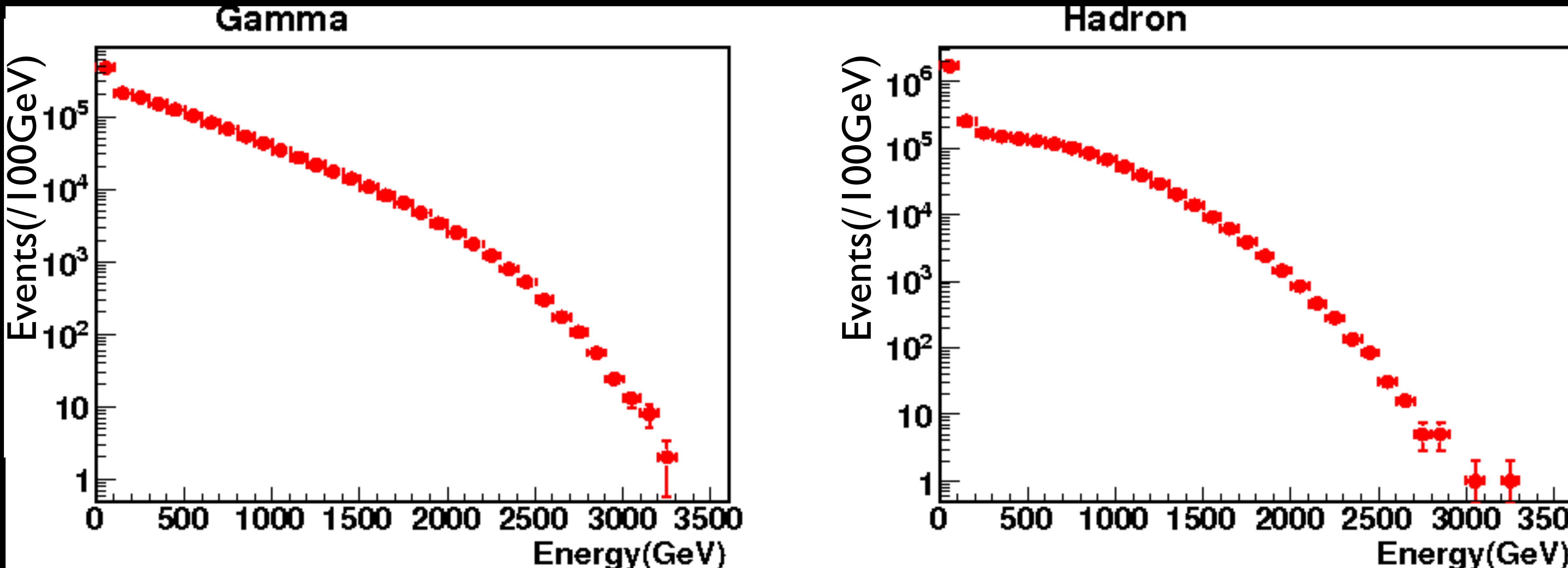
Event display of π^0(2-gamma)







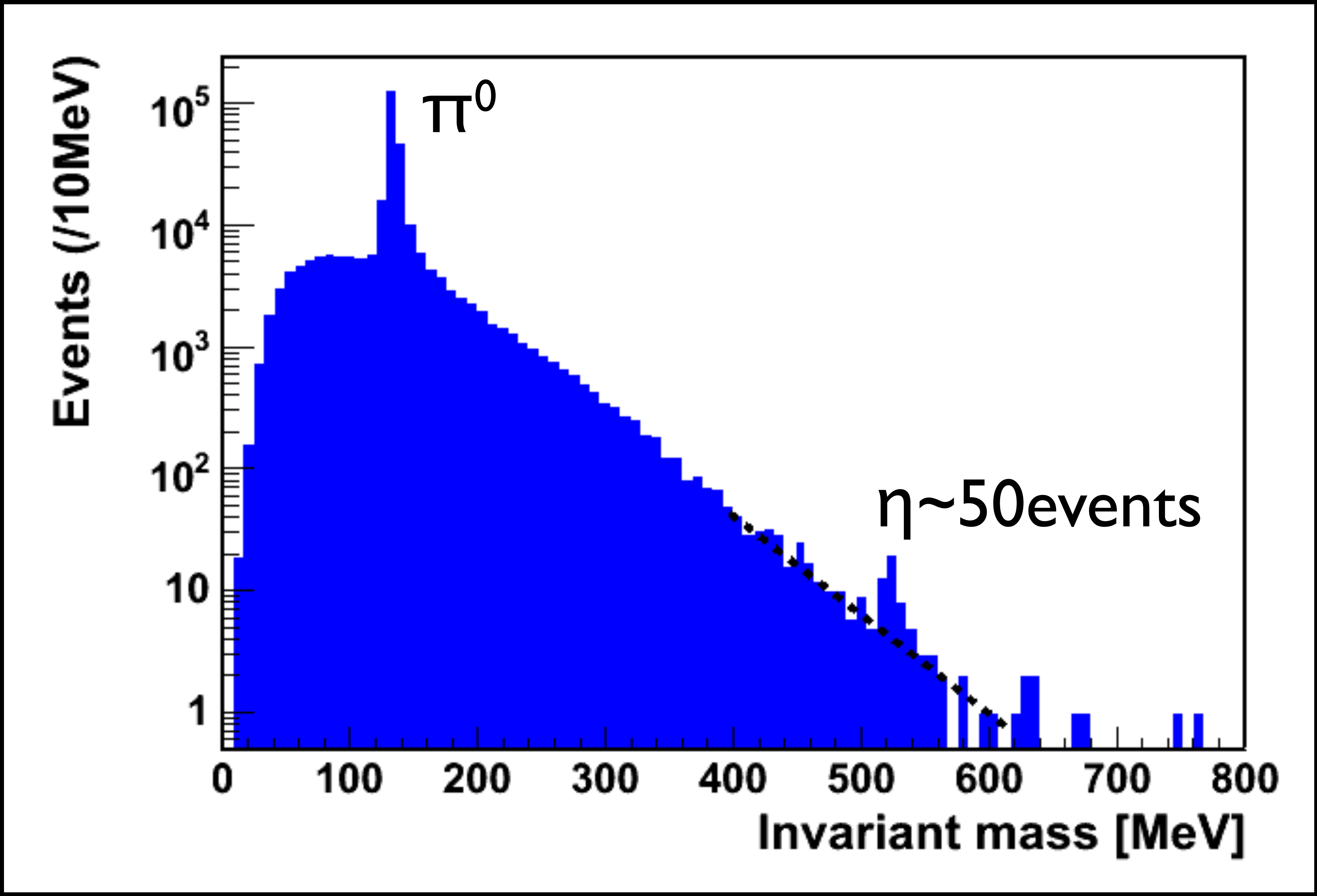
Spectra of 7TeV data



- High statistics
  - Only 1% of total data are used
- Very clean sample
  - Beam-gas BG is ~ 1%

Ongoing studies:
- Model discrimination
- η, strange meson
- LPM effects

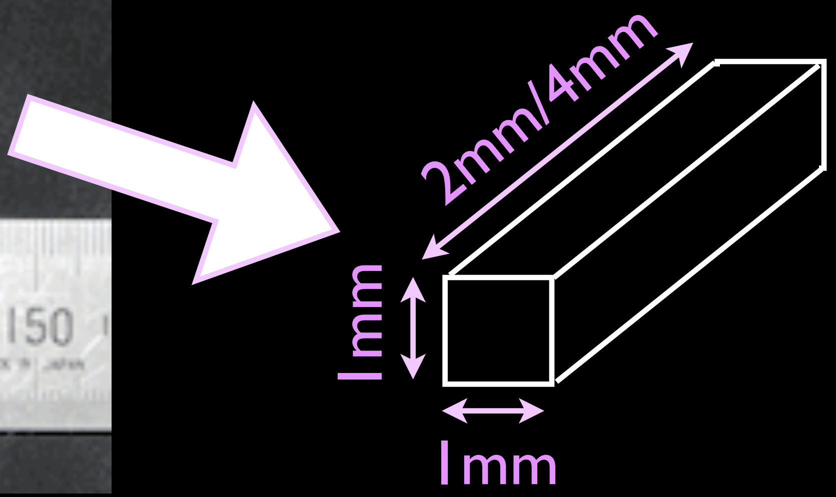
η search


π0
η~50events
Events (/10MeV)
Invariant mass [MeV]
1
10
10^2
10^3
10^4
10^5
0
100
200
300
400
500
600
700
800

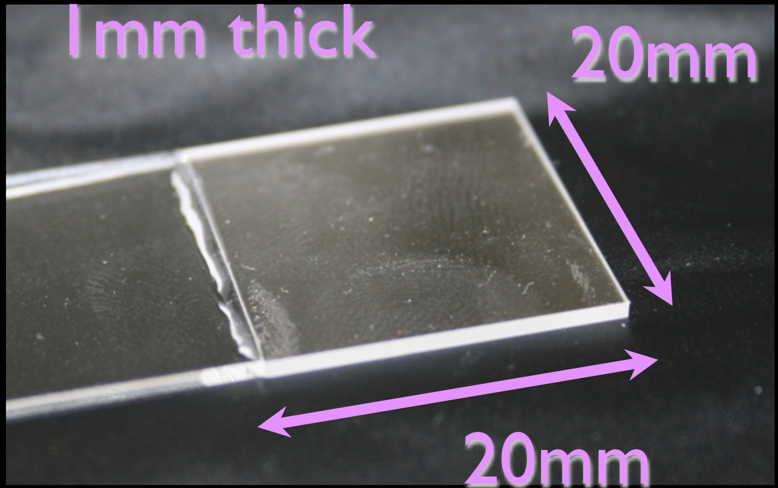
Removal and next phase

- LHCf will go out from the TAN(LHCf site) day after tomorrow.
  - Plastic scinitillator degrades a few % by ~6Gy on July 15th(~200nb^{-1}).
- "Post"-calibration by a SPS test beam are planned on October.
- Revisit LHC at the next energy upgrade. R&D and fabrication of radiation-hard GSO scinitillator are on-going for the "phase-2" of the LHCf detector.

GSO bar



GSO scintillator



Conclusions

- LHCf has started physics program quite successfully.

  - 100K showers at 900GeV (Run2009 + 2010)

  - 35M showers and 330K π^0 at 7TeV (Run2010 until May technical stop)

- Detectors work fine and stably.

  - Almost negligible beam-gas background ~1%

  - The π^0 peak demonstrates good performance as expected.

- Detectors will leave LHC tunnel on Tuesday.

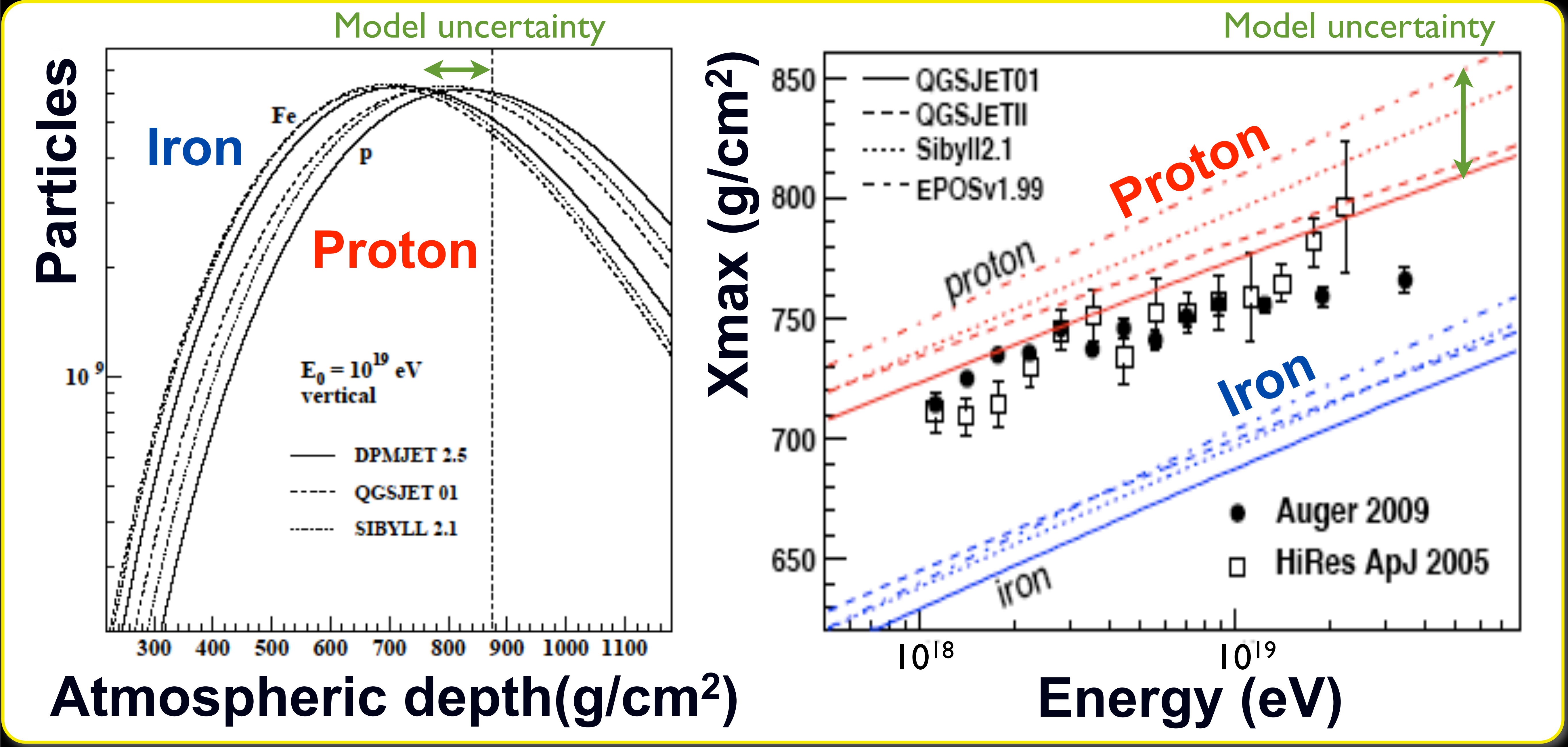
- Rapid progress in analysis.

  - 900GeV results and 7TeV results, need more precise studies

  - Finalizing SPS beam test data (energy scale, PID and hadron shower)

Supplements

Hadron interaction models

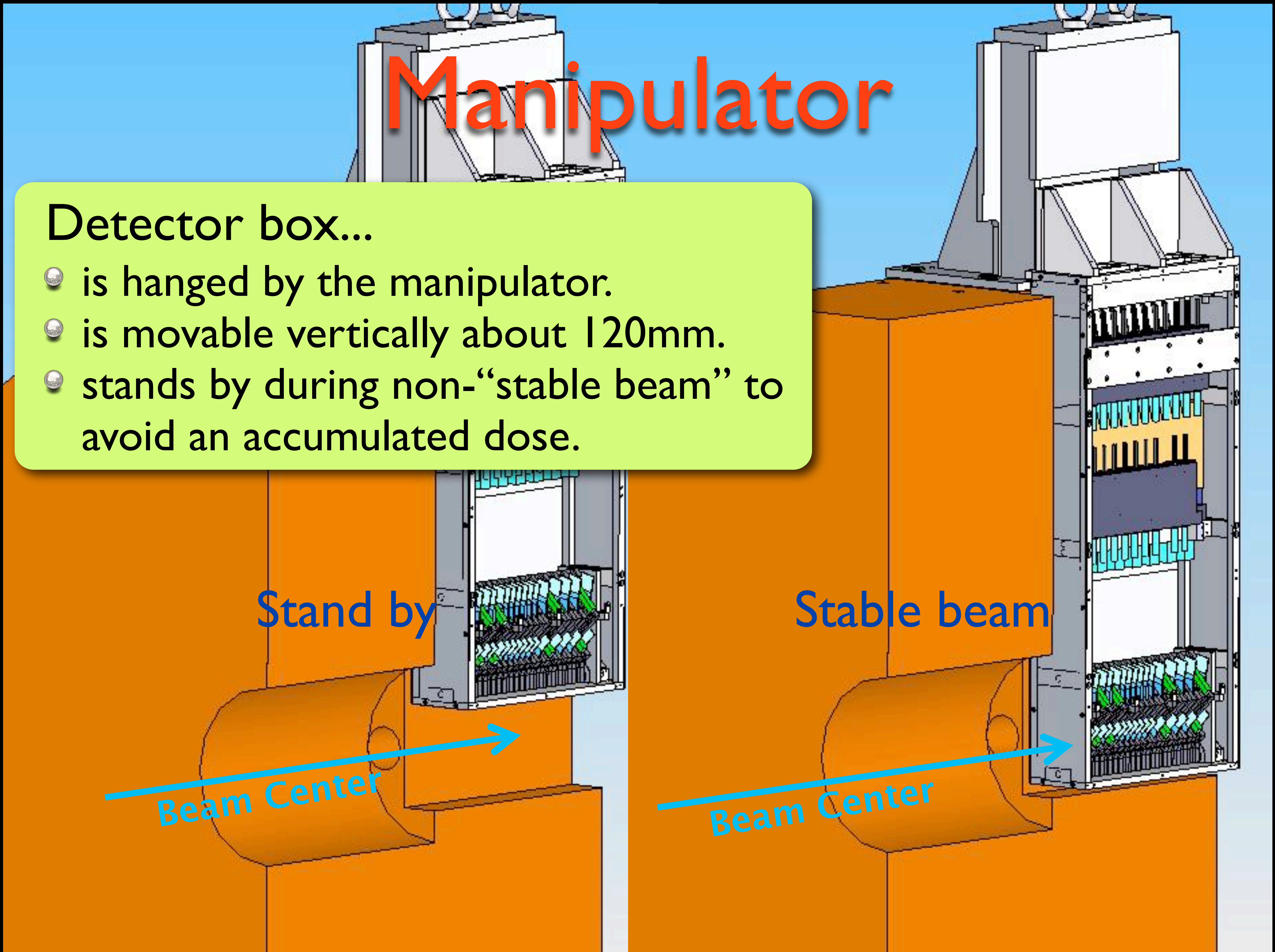


Measurements of very forward particles using the highest energy accelerator have a key to constrain the uncertainties unavoidable in the high-energy cosmic ray experiments.

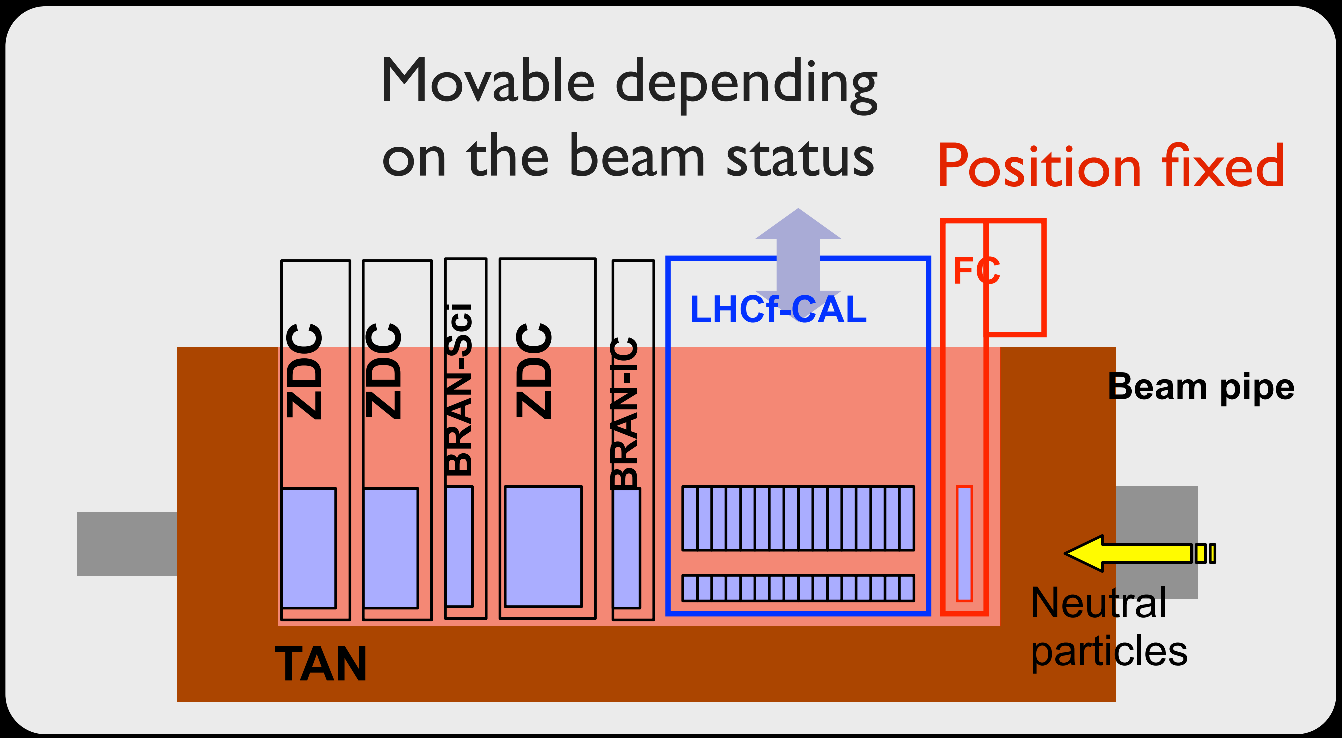
Manipulator

Detector box...

- is hanged by the manipulator.
- is movable vertically about 120mm.
- stands by during non-“stable beam” to avoid an accumulated dose.

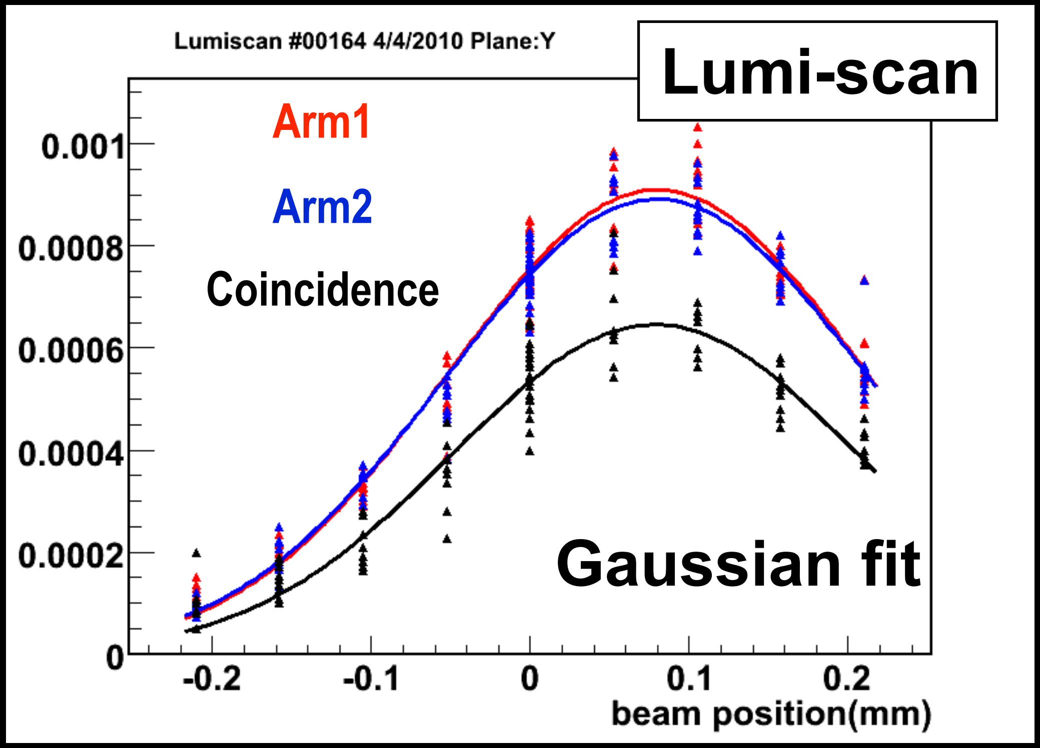


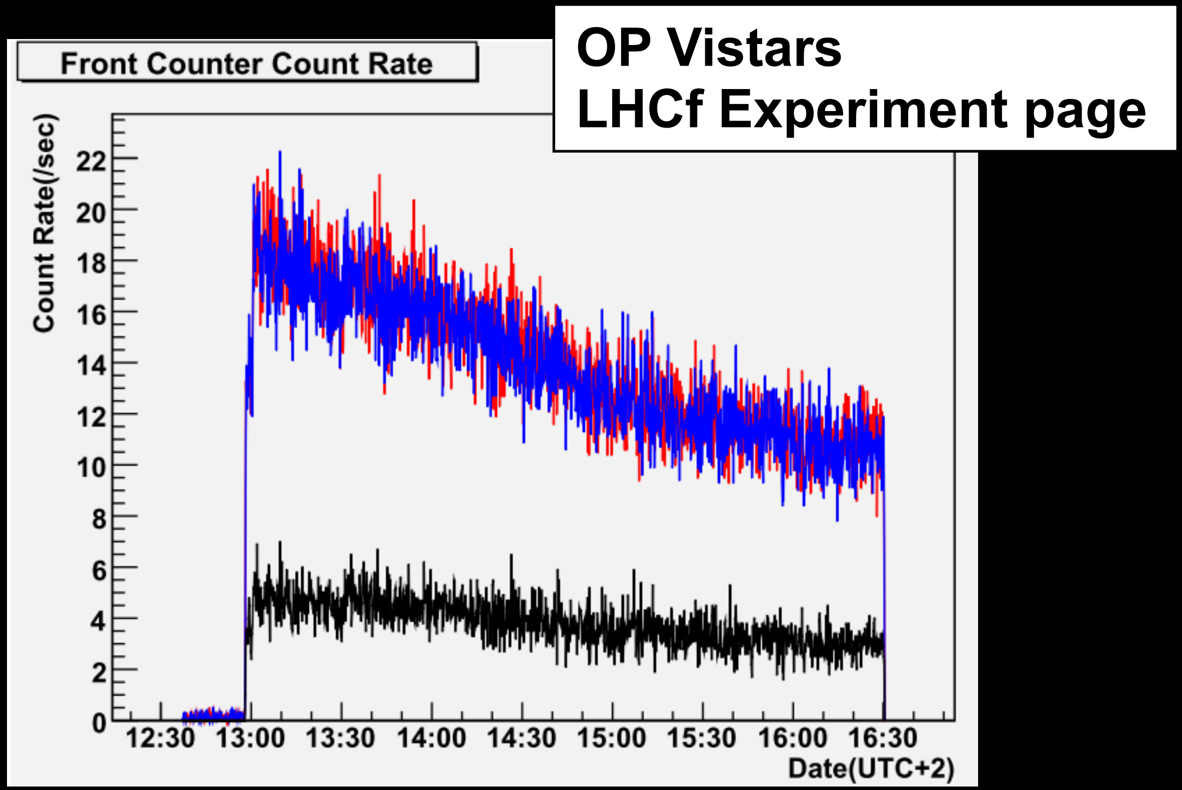
Front Counter



Front counter...

- consists of 4 scintillation counters, 2 for X and 2 for Y.
- has large aperture(80mmx80mm).
- can work prior to the stable beam declaration.
- acts as the luminosity monitor and beam-gas BG monitor.

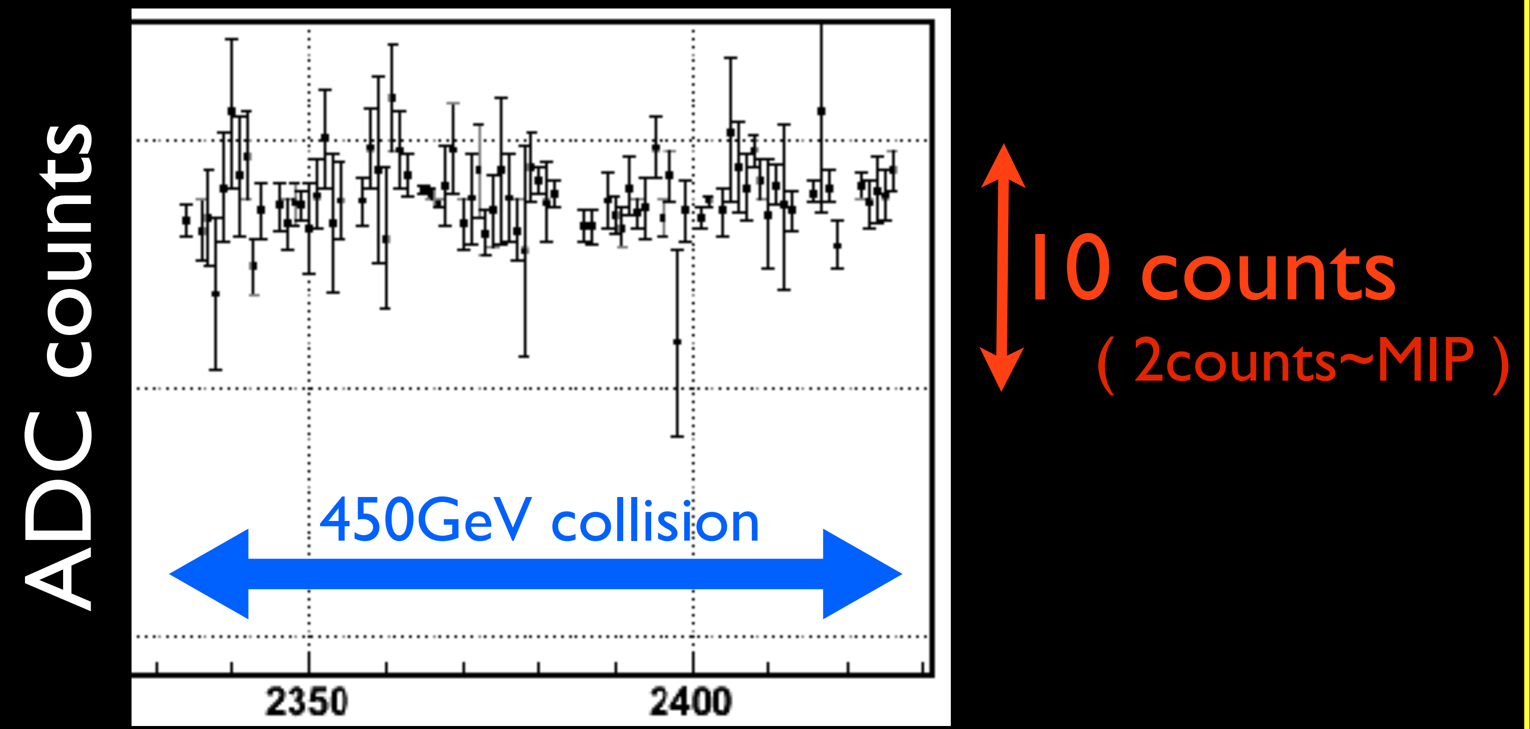


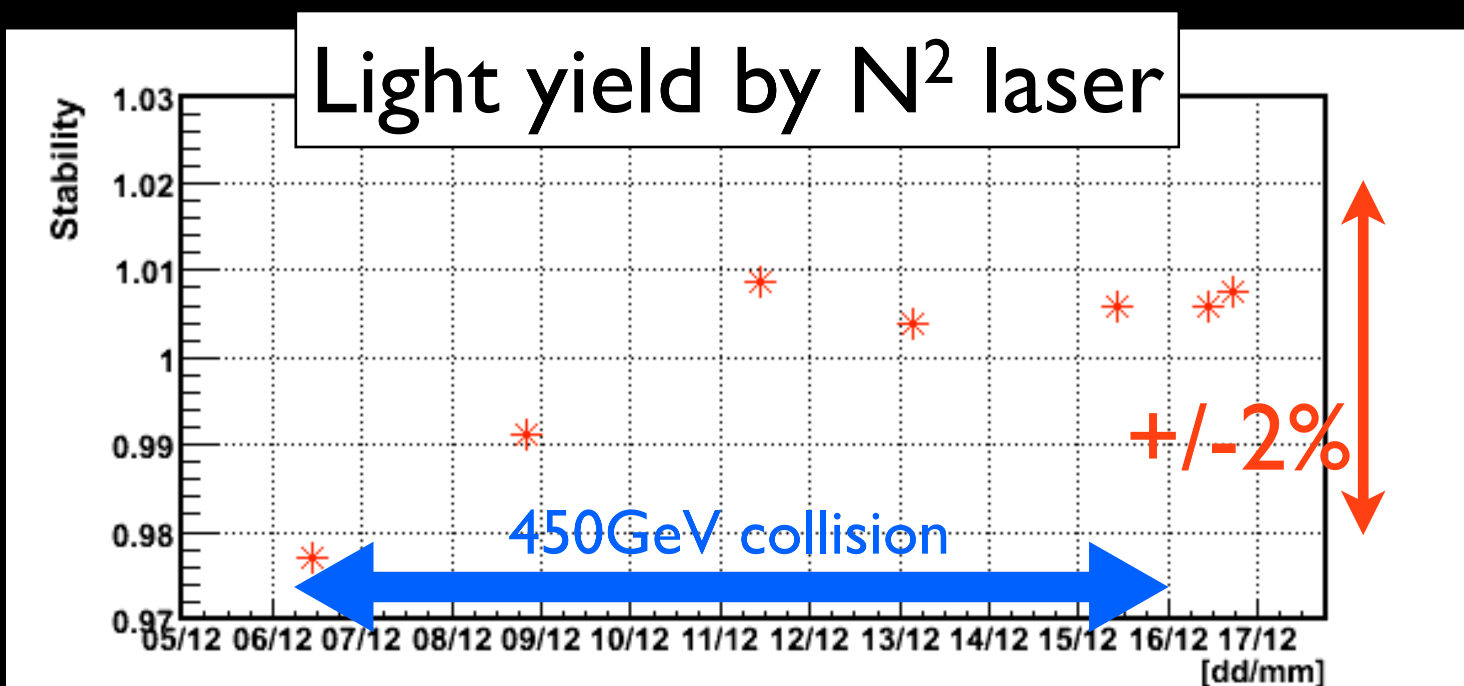


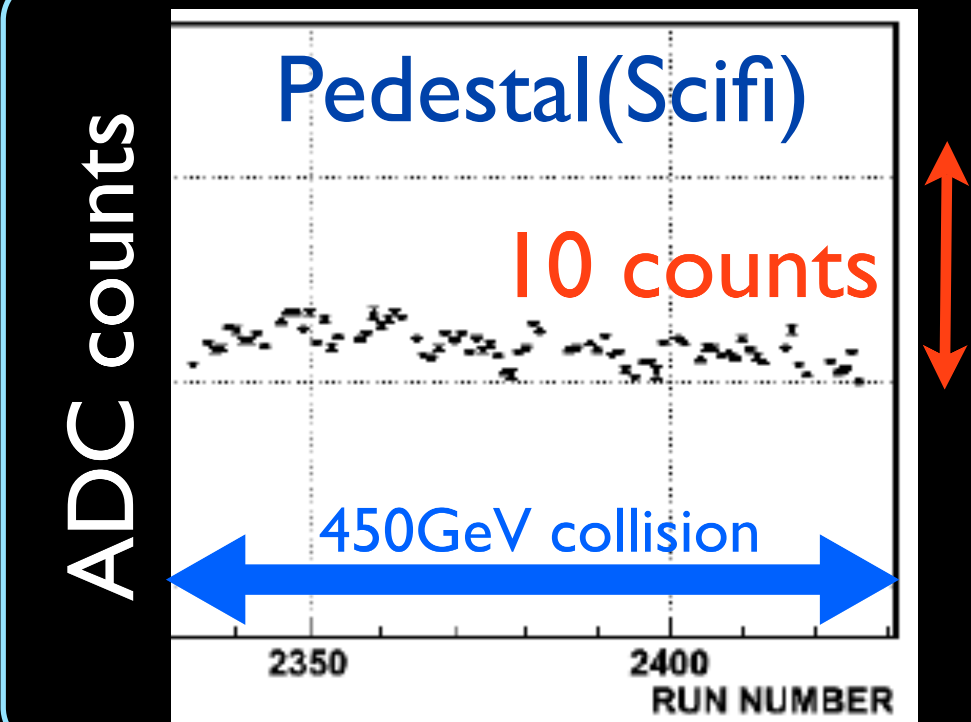
Detector Stabilities

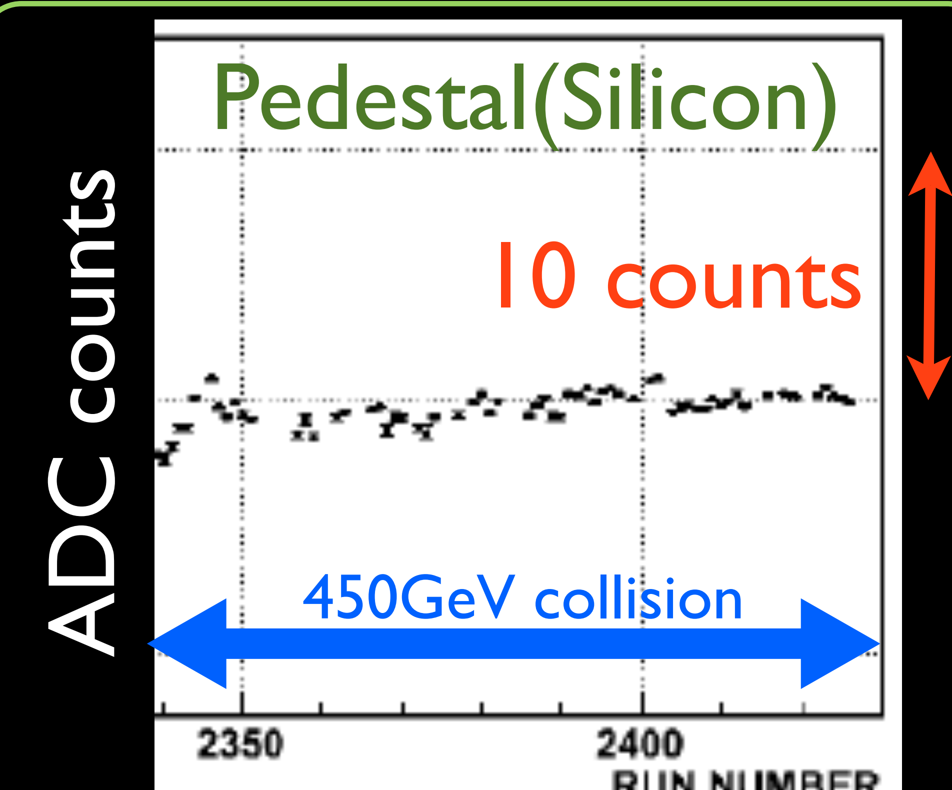
Calorimeter

Pedestal fluctuation





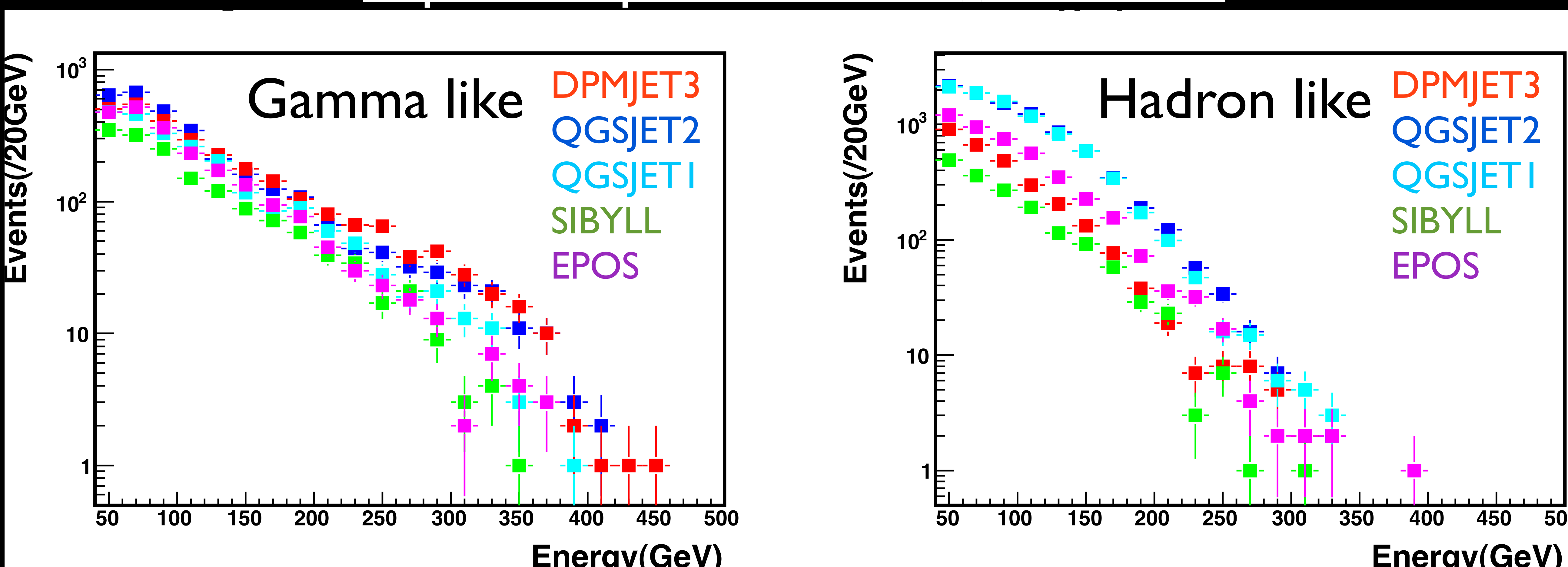




Analysis of 900GeV run

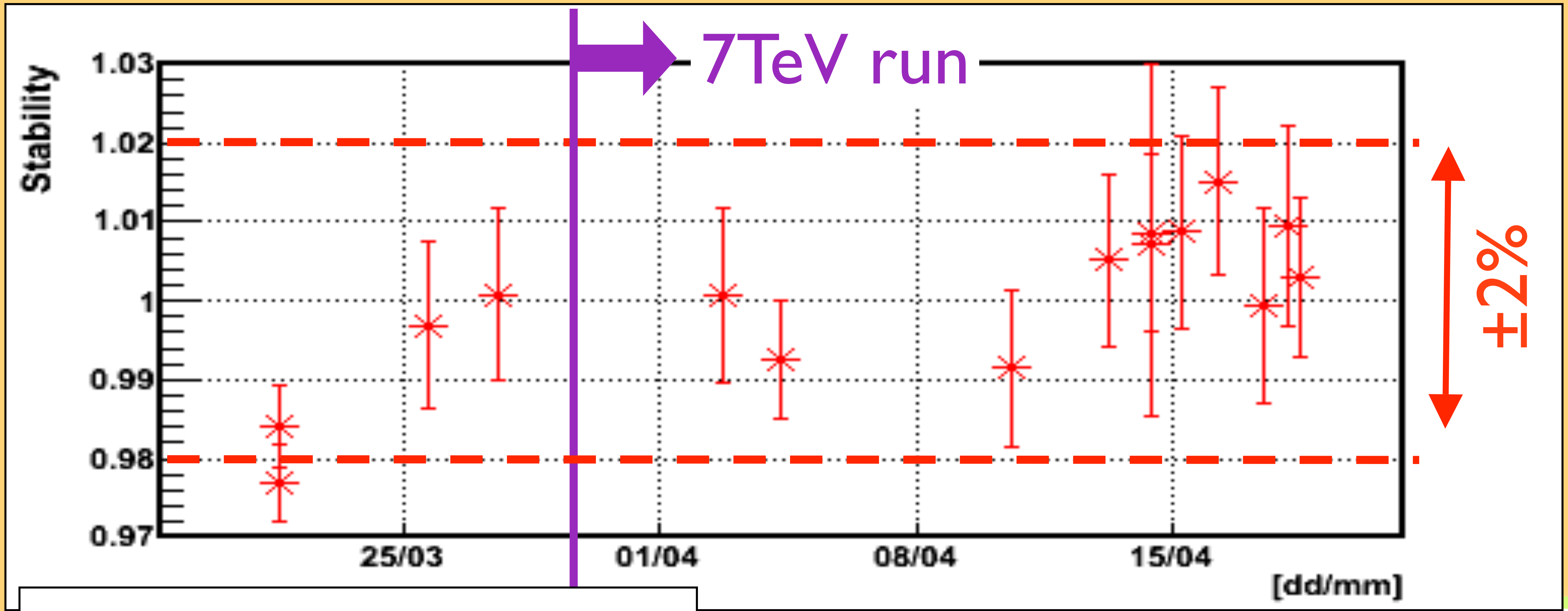
- Stable beams at 900GeV, Dec. 6th-15th in 2009.
  - ~5x10^5 collisions at IP1.
  - 2,800 and 3,700 showers in Arm1 and Arm2.
- Absolute energy calibration by π^0 taken at 7TeV run.

Expected spectra with 10^7 collisions.



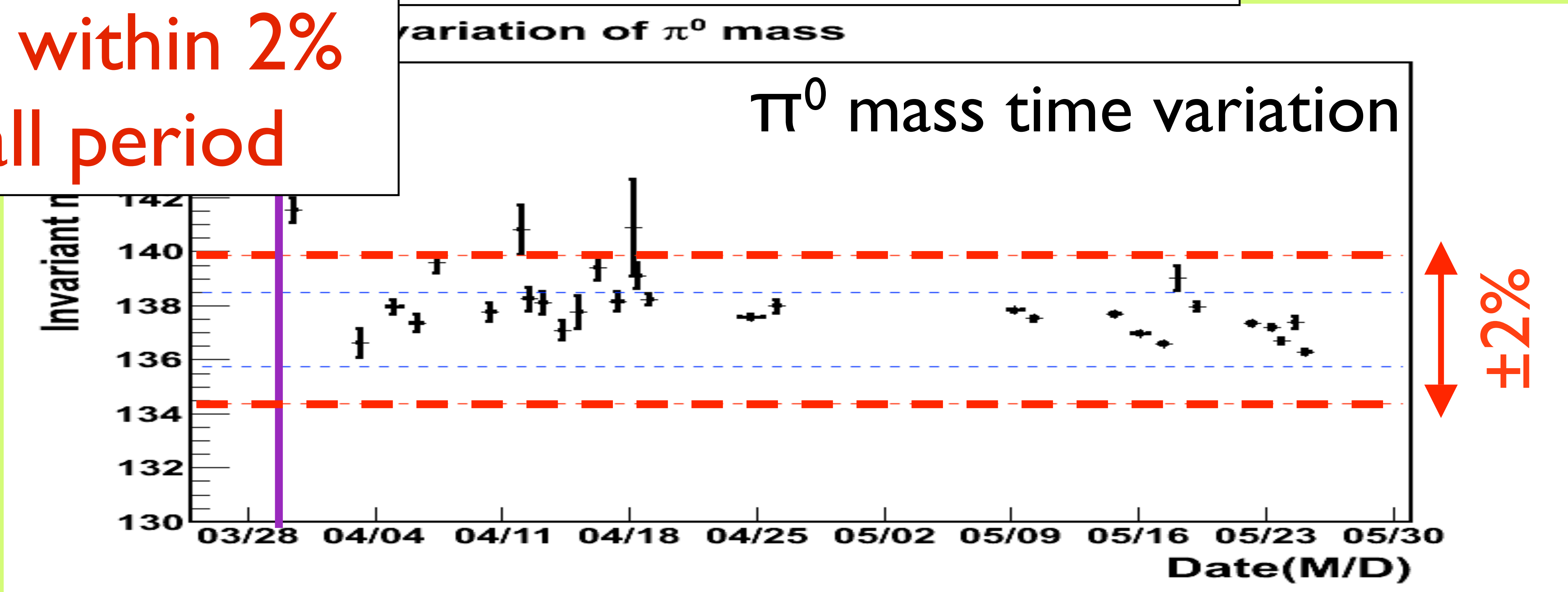
Large model dependence can be seen even in 900GeV.

Detector stability

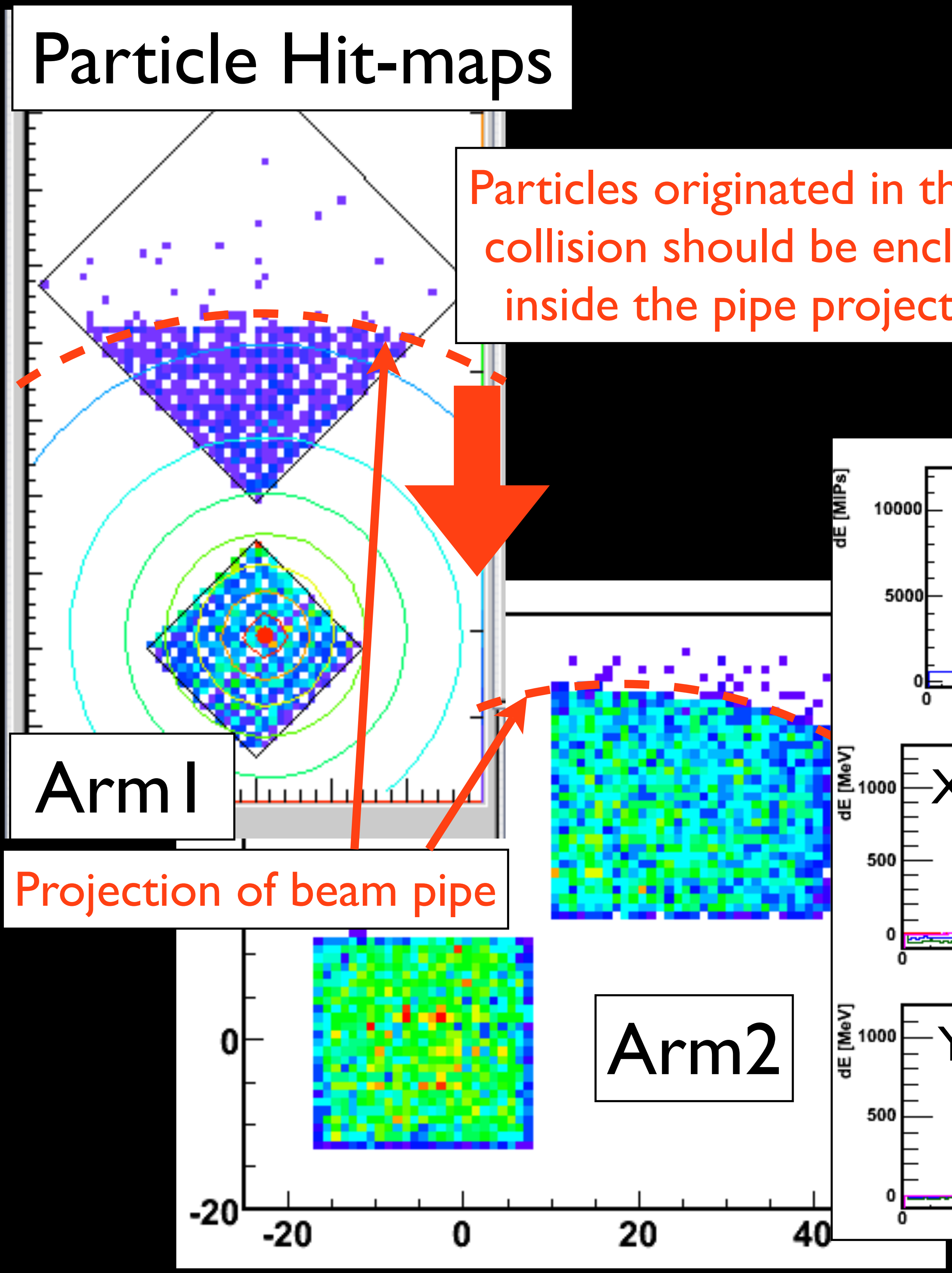


Gain calibration with N^2 laser for scintillator layers

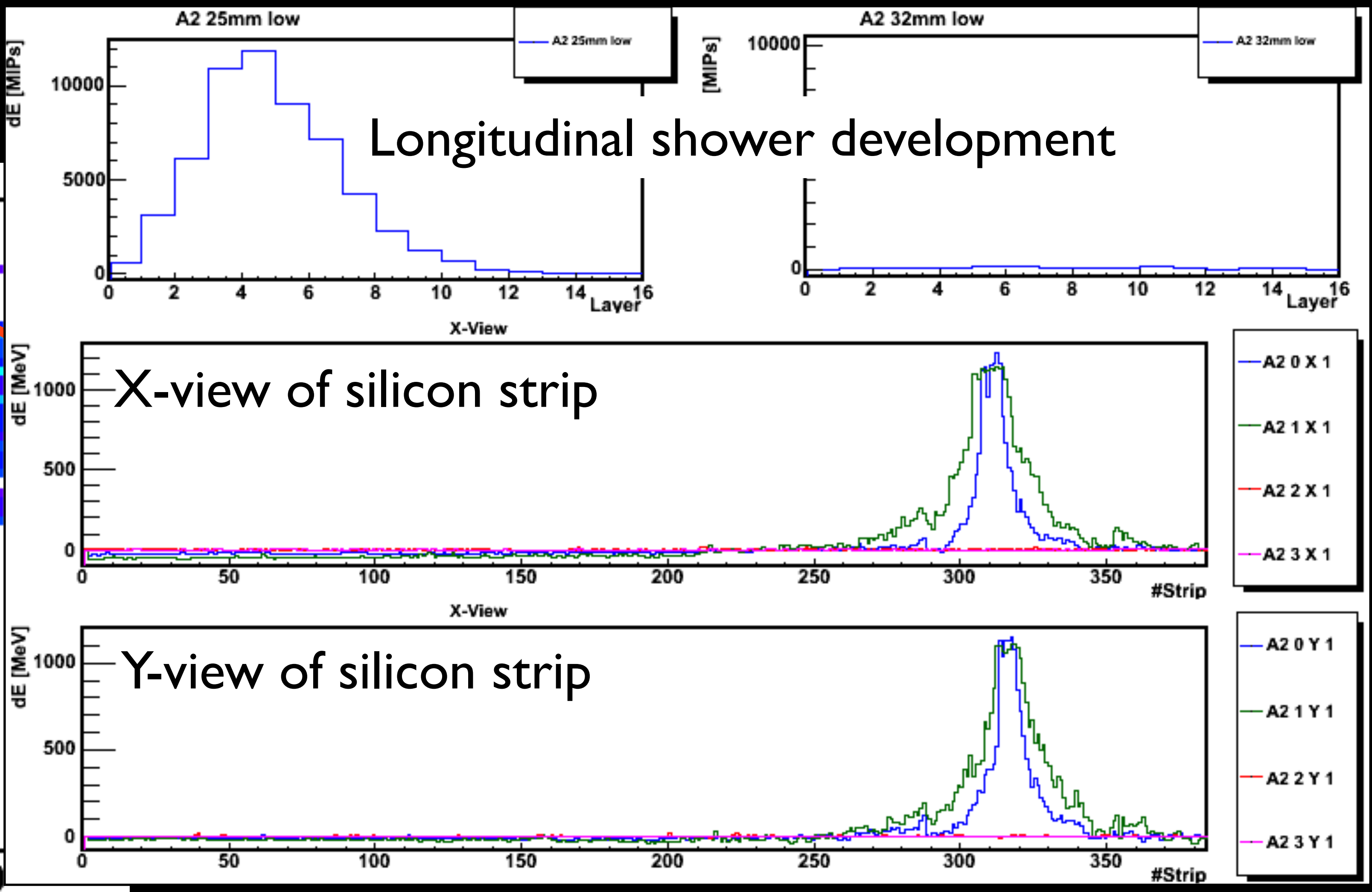
Stable within 2% for all period



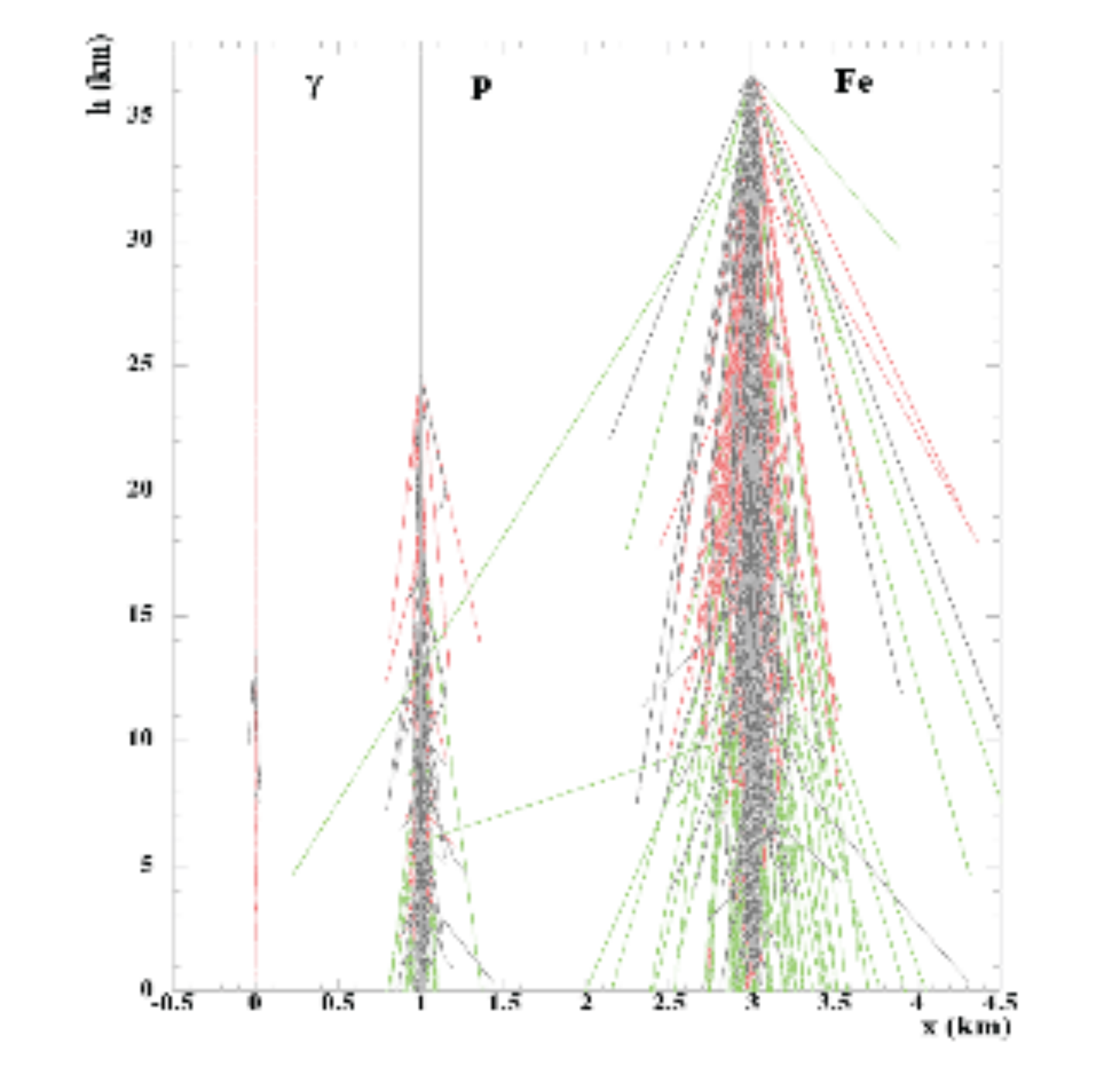
Event display

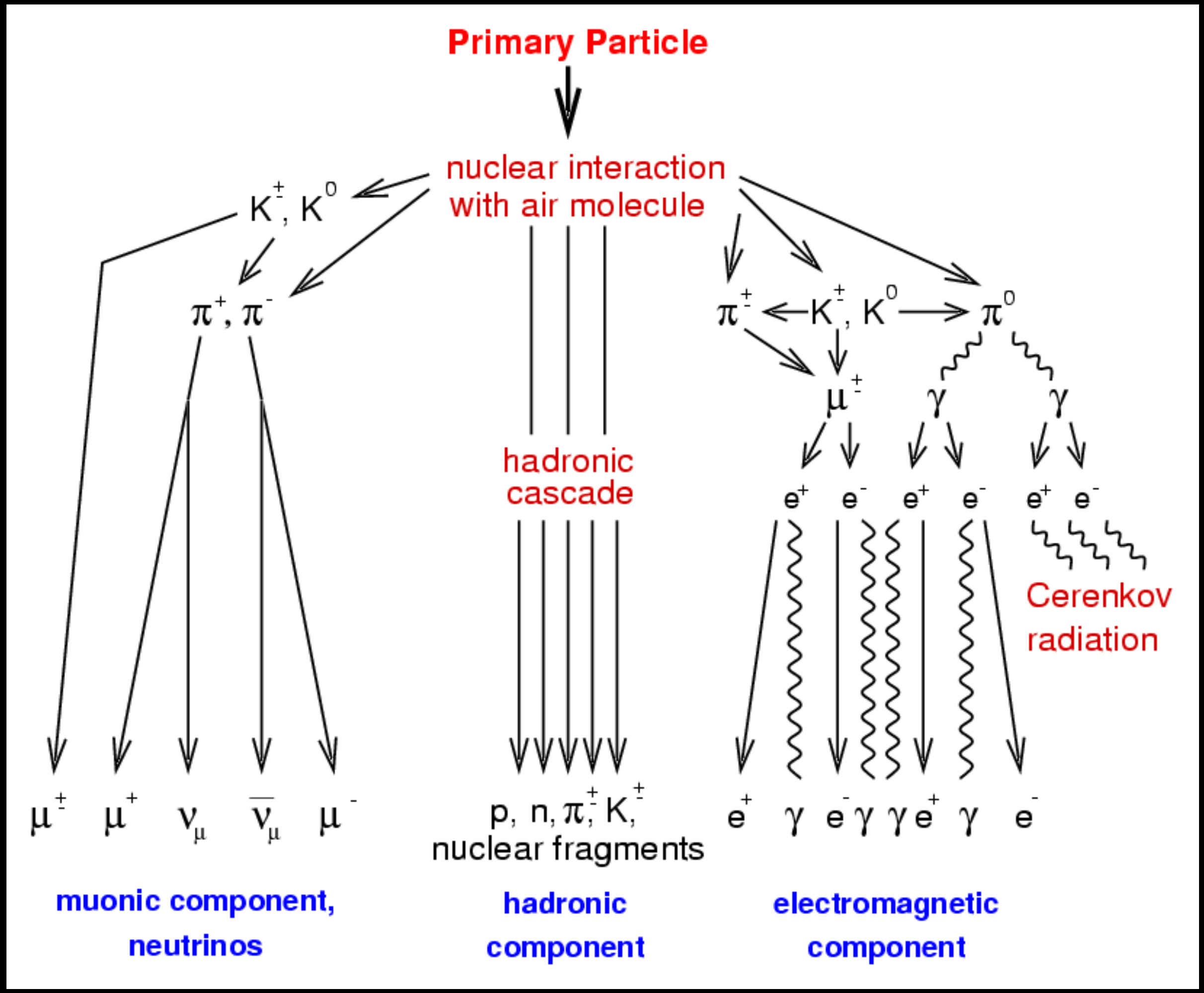


Gamma-like, E_{rec}=1TeV

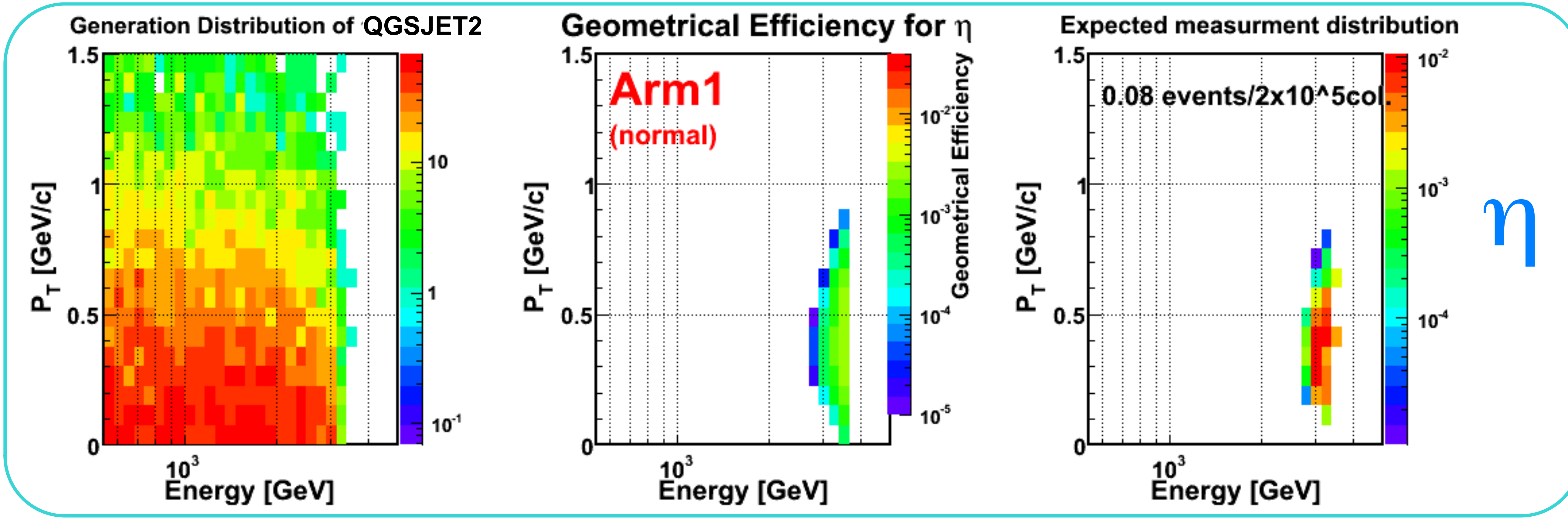


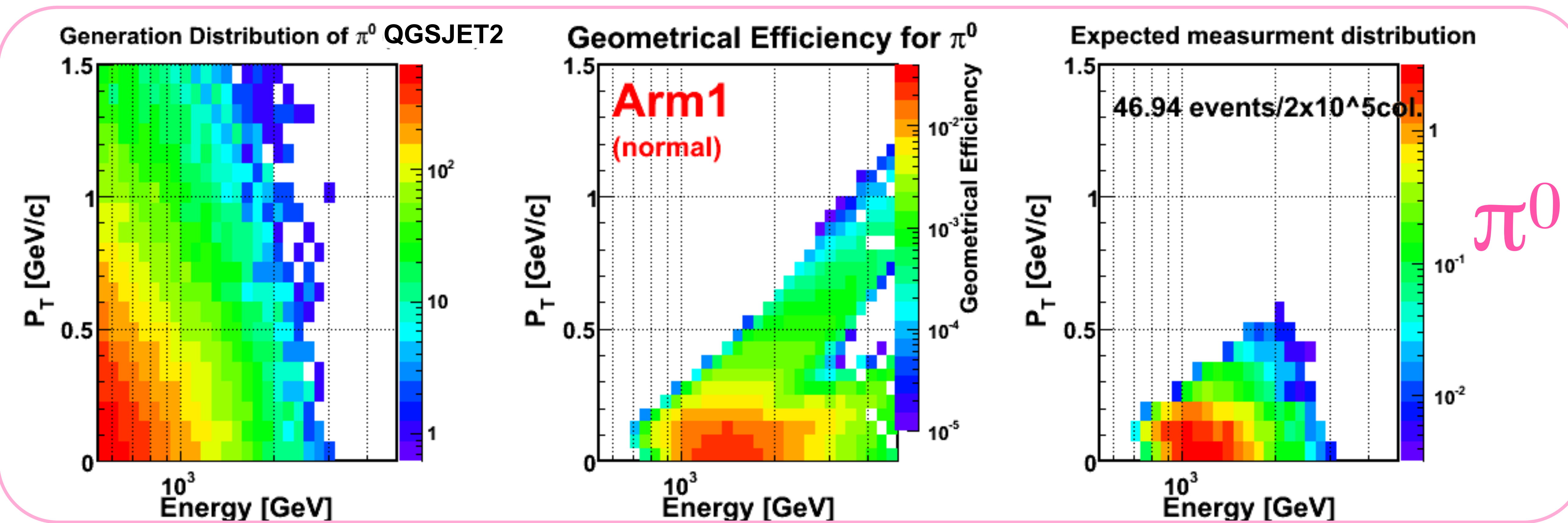
Air shower development





QGSJET2, Arm1-Normal



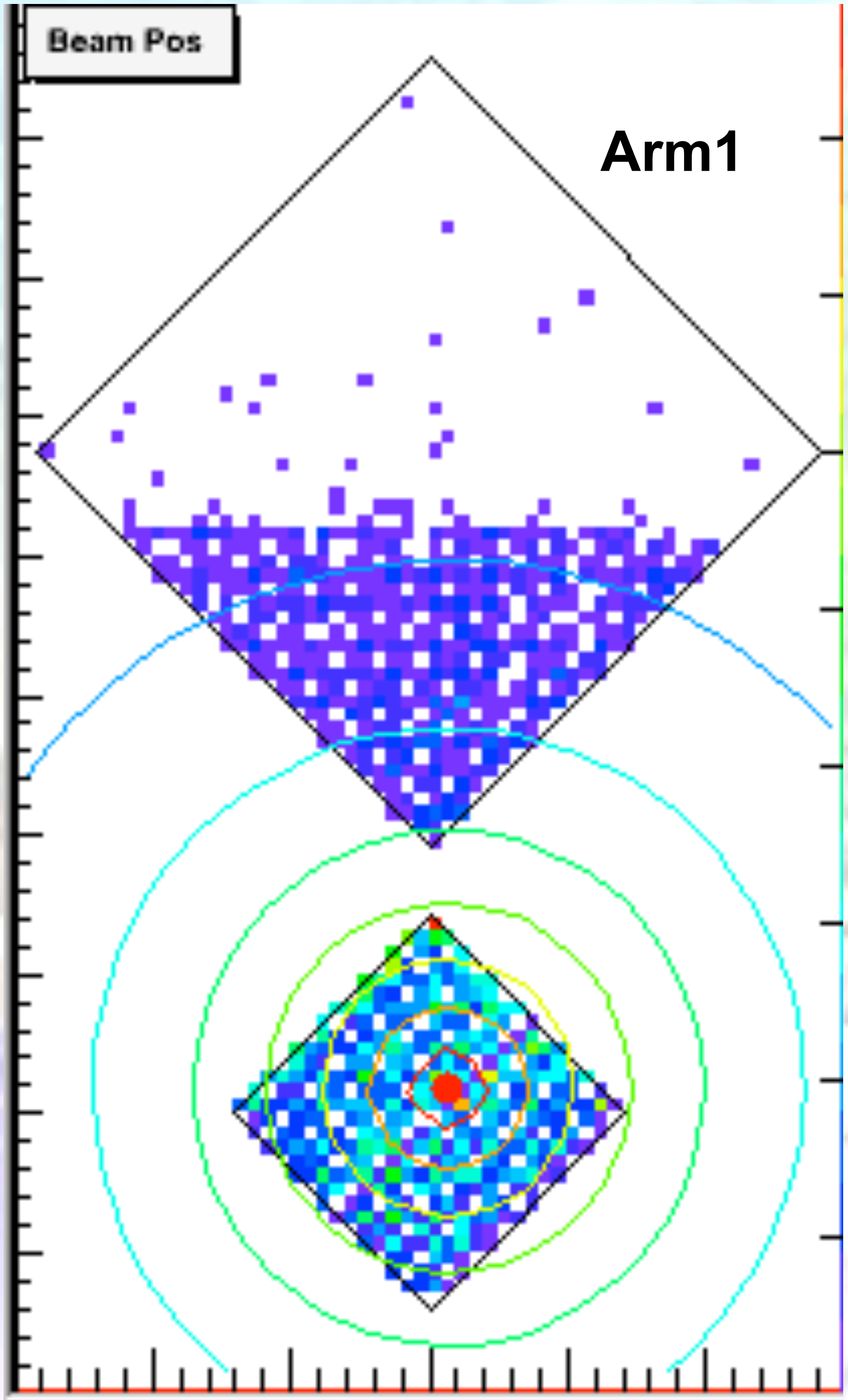


Summary of Expected number of events

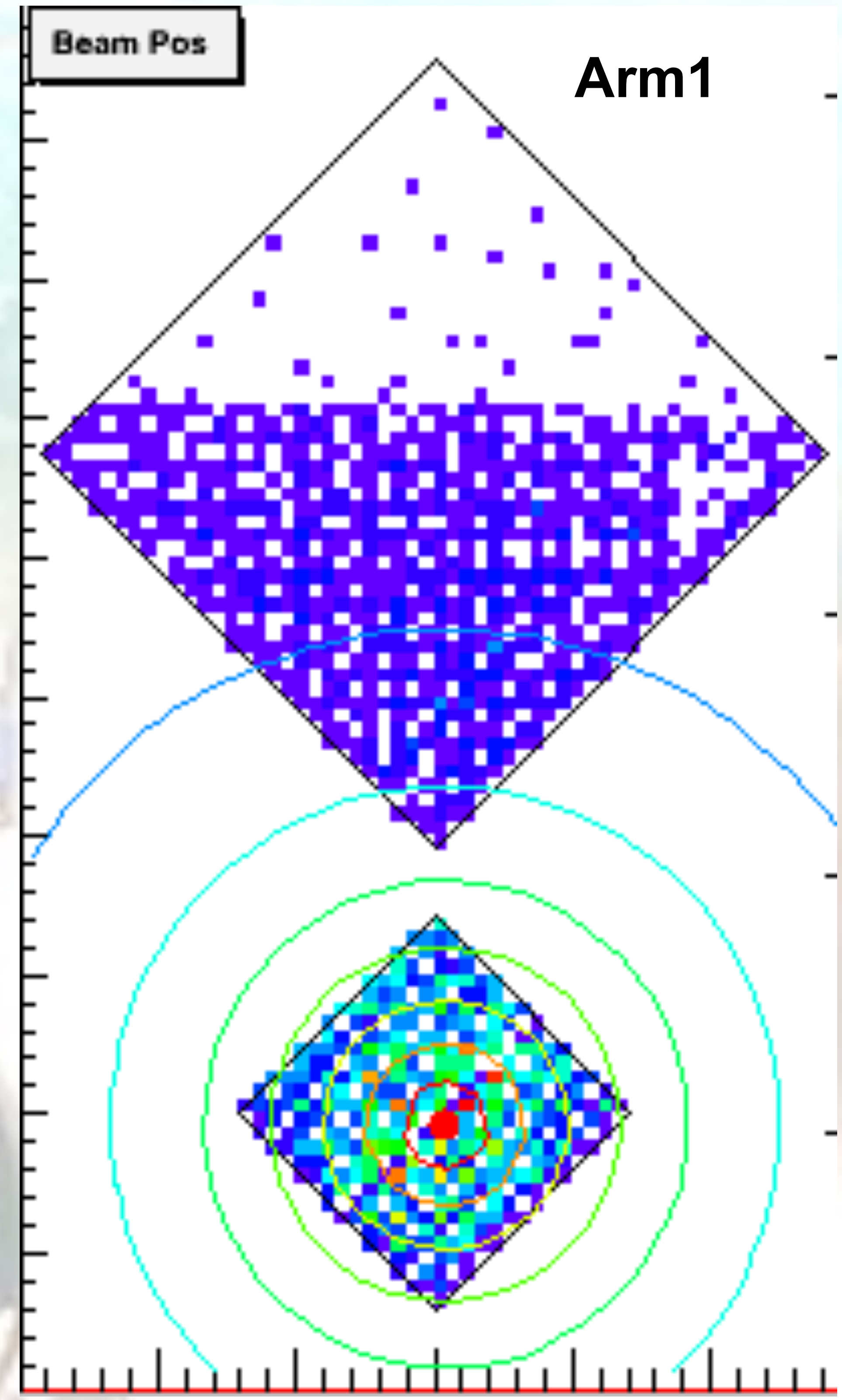
	QGSJET2			SIBYLL			Pythia		
	η	π^0	η/π^0	η	π^0	η/π^0	η	π^0	η/π^0
Arm1 (Normal)	0.08	46.9	0.002	0.01	46.7	0.0002			
Arm1 (-20mm)	7.35	238.4	0.031	0.21	191.9	0.0011			
Arm2 (Normal)	1.6	123.7	0.012	0.10	110.8	0.0009	0.15	150	0.0010
Arm2 (-10mm)	3.36	191.3	0.018	0.21	165.1	0.0013	0.1	169	0.00059

Acceptance gain due to Crossing Angle

No crossing angle



100 μrad crossing angle



A very significant gain in acceptance is clearly visible!